

Affected Environment

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AFFECTED ENVIRONMENT

ELK POPULATION

Population Size and Growth

Since 1969, the Rocky Mountain National Park / Estes Valley elk population has more than tripled. Population estimates peaked between 1997 and 2001, with annual estimates ranging from about 2,800 to 3,500. Since 2002, winter estimates in the park and Estes Valley outside the park have declined, ranging from about 1,700 to 2,200.

The population includes three subpopulations that exhibit different population dynamics and migration patterns (Larkins 1997, Lubow et al. 2002): 1) Moraine Park / Beaver Meadows (referred to as Moraine Park), 2) Horseshoe Park, and 3) the Town of Estes Park. Elk tend to stay within these areas, although 15% regularly move among subpopulations. The population dynamics of the Moraine Park and Horseshoe Park subpopulations do not differ and will be collectively referred to here as the park subpopulation. Elk population dynamics are different between the park and town subpopulations.

After lethal reduction activities within Rocky Mountain National Park ended in 1968, the park subpopulation initially increased at an annual rate of 6.5% and then gradually slowed to reach an estimated carrying capacity of approximately 1,069 animals in 1991 (Lubow et al. 2002). Since that time, the size has remained stable, fluctuating around approximately 1,000 animals. The population-based carrying capacity estimate of 1,069 is consistent with three other estimates based on either ecosystem simulation modeling or forage biomass and energy considerations (Hobbs et al. 1982, Coughenour 2002, Singer et al. 2002). The elk population size on the park winter range areas is primarily limited by the amount of available forage on the winter range (Hobbs et al. 1982, Coughenour 2002, Lubow et al. 2002, Singer et al. 2002), which is strongly related to weather conditions. Assuming existing habitat and continuation of weather patterns that occurred in the second half of the 20th century, the park subpopulation is expected to continue to fluctuate between 800 and 1,100 animals (Coughenour 2002).

Elk did not winter in the Town of Estes Park in noticeable numbers until about 1975 to 1980 (Hobbs et al. 1982). The town subpopulation increased at an estimated maximum average rate of 11% from 1979 to 1983 and was still increasing 5.2% per year from 1991 to 2001. Although the origin of the town population was likely emigration from the park, the subsequent growth of the town subpopulation appeared to be independent of the park subpopulation (Lubow et al. 2002). Population estimates reached a high between 1997 and 2000, with annual estimates ranging from about 2,000 to 2,500 elk. Estimates from 2001 to 2005 have ranged between about 1,000 and 1,400 elk in the Estes Valley area. These lower estimates coincided with increased numbers in the park (2001) and/or increased observations of elk from the Rocky Mountain National Park area east of the Estes Valley (2002-2003), as well as increased hunter harvest outside the park (see "Distribution and Movements" section).

The potential for further population growth in the town subpopulation is uncertain. Multiple and conflicting carrying capacity estimates have been made for the Estes Valley outside the park with corresponding population size estimates ranging from Coughenour's 1,400 to 2,000 using an ecosystem modeling based approach (2002) to Lubow et al.'s 2,454 to 3,284 using a population modeling based approach (2002). Recent observations suggest that the elk subpopulation in town may be stabilizing, but this has also coincided with dry weather conditions and alterations in migration patterns. Thus, the stability in elk numbers or changes in habitat use may not be a long-term trend (Monello et al. 2005).

Carrying capacity in the town area in 1996 was estimated to be only 5% less than if the area was still in a pristine, natural condition (Coughenour 2002, Singer et al. 2002). Development and the creation of Lake Estes reduced the land area available for elk foraging, but fertilization and irrigation enhanced the productivity of other areas (e.g. golf courses). Future carrying capacity will be driven by weather conditions as well as the balance between further development and artificial enhancement of the landscape.

Sex and Age Composition

As the population size increased, the ratio of calves:100 cows and spikes:100 cows decreased in the park and in town (Bear 1989, Lubow et al 2002). Estimates based on population modeling indicate a decline from about 36 to 28 calves:100 cows in the park between 1986 and 2001, and from about 50 to 30 calves:100 cows in town between 1978 and 2001 (Lubow et al. 2002). Spike ratios also declined steadily over the same time periods, from about 12 to 7 spikes:100 cows in the park and 11 to 5:100 cows in town (Lubow et al. 2002). Unpublished data collected by the park and the Colorado Division of Wildlife show that from 2002 to 2005, the ratios of calf:100 cows have ranged between 21 to 31 in park and 29 to 46 in town and ratios of spikes:100 cows have ranged between 4 to 6 in the park and 8 to 24 in town.

Bull ratio changes initially declined and then rose steadily in the park but remained steady in town (Lubow 2002). Modeled ratios in 2001 indicated about 22 bulls:100 cows in the park, and 6 bulls:100 cows in town. The lower proportion of bulls in town than the park likely reflects the differential effect of hunter harvest outside the park on the town subpopulation (Lubow et al. 2002). Unpublished data collected by the park and the Colorado Division of Wildlife show that from 2002 to 2005, bull:100 cow ratios have ranged between 5 to 21 in the park and 12 to 27 in town.

Elk Densities

Elk group sizes during winter can range from a single individual to over 600 animals in Moraine Park and the golf course areas in Estes Park (Larkins 1997). Elk densities are variable in the park, with high (76 to 170 elk/mile²) to very high (171 to 286 elk/mile²) concentrations on about 7% of the winter range, centered in Moraine Park / Beaver Meadows (Singer et al. 2002). The remainder of the winter range generally has moderate (26 to 75 elk/mile² on 11% of the winter range) to low (<26 elk/mile² on 82% of the winter range) densities (Singer et al. 2002). Although elk use lower-density areas of the winter range to rest or as they move between areas, time spent foraging is highly concentrated on a small percentage of the winter range (Singer et al. 2002). Elk densities on core winter range areas that are greater than 260 elk/mile² are the highest concentrations ever reported for a free-ranging population in the Rocky Mountains (Monello et al. 2005). Evidence from various research conducted in the park indicates that the high densities of elk in specific areas are as significant as the total population size in terms of impacts on vegetation. Elk are generally less concentrated on summer range areas.

The average density in Estes Park is 74 elk/mile². Site-specific density information is not available for Estes Park, but a similar pattern exists with very high concentrations in areas with excellent foraging conditions (e.g. golf courses) and lower concentrations in other areas (e.g. roads and parking lots). Elk use essentially all parts of the Estes Valley, with concentrations occurring in the area between Dry Gulch and Devil's Gulch Road, along U.S. highway 34, the Crocker Ranch area, on both golf courses, and between Fish Creek and Colorado Highway 7 (Larkins 1997).

Distribution and Movements

The Rocky Mountain National Park / Estes Valley elk population spends approximately seven months per year on winter range and three months on summer range. The remaining two months are spent on or in transition between these two ranges (see Appendix C). Within their seasonal ranges, elk move in response to various factors, including weather and hunting (Larkins 1997). Elk respond to hunting by moving from areas that are open to hunting to areas where hunting is prohibited.

The elk population exhibits large, seasonal migrations between primary winter and summer ranges (Figure 3.1). The timing of migration depends on weather, in particular snow depth, which determines when forage on the summer range will become available. Generally between [75% and 90%](#) of the population migrate to higher elevations or the Kawuneeche Valley for the summer (Larkins 1997). Elk from the three major winter range areas exhibit distinct migration routes to and from their summer ranges (Larkins 1997). Elk that winter in Moraine Park / Beaver Meadows migrate over the Ute Trail and to the Kawuneeche Valley, where they calve, and most remain for the summer, although some migrate back to alpine areas for the summer. Elk from Horseshoe Park and Estes Park migrate up the Fall River drainage and spend summer in alpine areas of the park. However, the timing of the migrations of the two subpopulations is different, with Horseshoe Park elk migrating to higher elevations in the Cache la Poudre and Fall River areas to calve, while elk from town calve in Horseshoe Park before proceeding to higher elevations for summer.

The primary winter range falls within park boundaries (Figure 1.1), extending from Cow Creek on the north to Hollowell Park on the south and west to Hidden Valley. Elk that winter in the park concentrate in two areas: Moraine Park / Beaver Meadows (8,140 feet) and Horseshoe Park (8,589 feet). A small group of elk (100 to 200 animals) winters on the alpine tundra. In general, about one-third of the Rocky Mountain National Park / Estes Valley population winters in the park (Lubow et al. 2002); however, park subpopulations make temporary cross-boundary movements out of the park to lower elevations, especially during snowfall events.

Most of the winter range is outside the park in the Estes Valley and on adjacent private and U.S. Forest Service Lands (Figure 1.1). The Town of Estes Park (7,522 feet) provides continuous elk winter range with Moraine Park and Horseshoe Park. Elk are attracted to the town area for several reasons, including extensive grasslands, some of which are nutritionally enhanced by fertilization (e.g., golf courses); limited predation in comparison to the park; and lack of hunting.

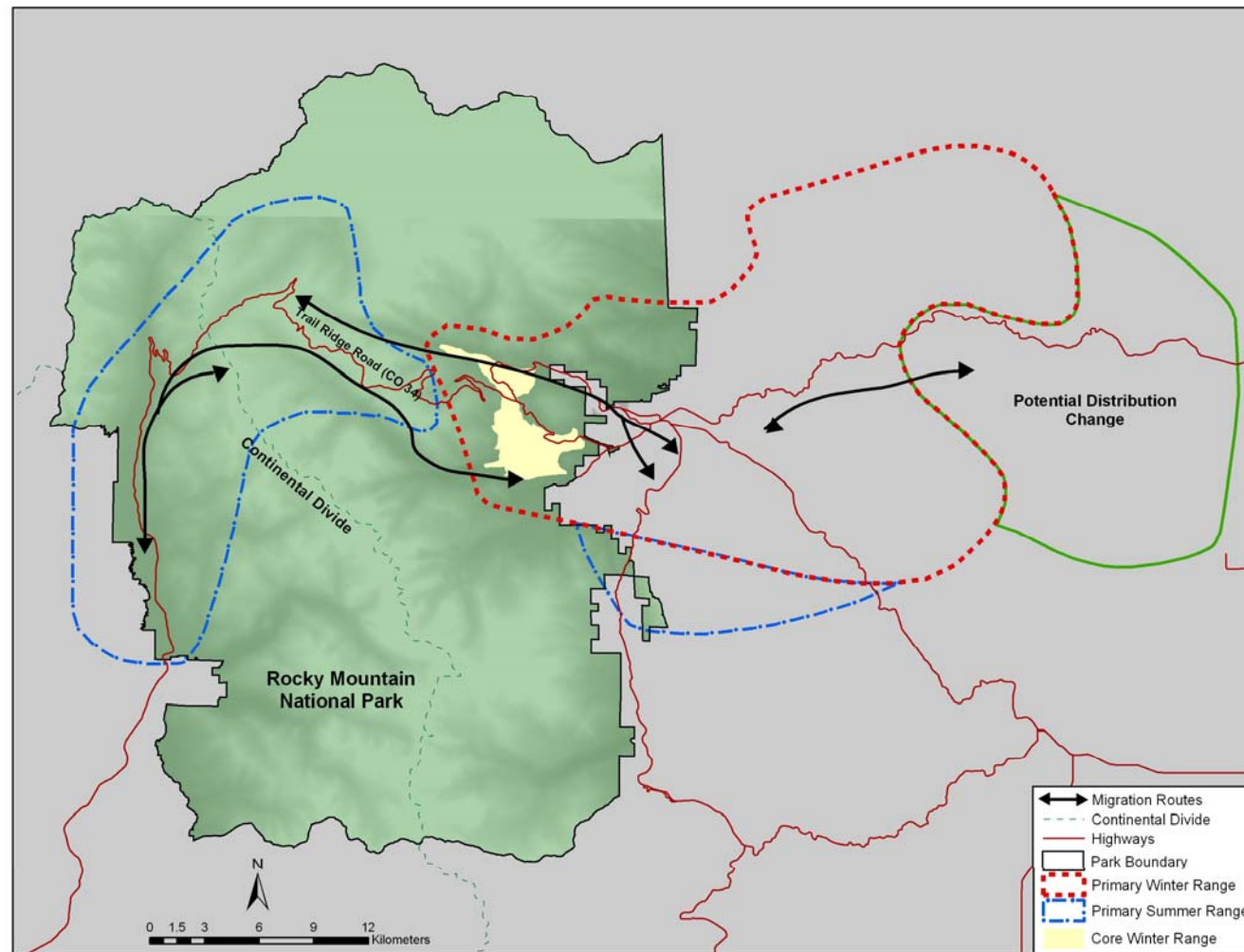


FIGURE 3.1: ELK MIGRATION ROUTES

In addition, the town lies at a lower elevation than winter range in the park, and consequently has lower snow depths and more favorable winter temperatures for elk (Singer et al. 2002). During winter, elk also range east of the Estes valley, with elk numbers and time periods varying depending on habitat conditions, snowfall, and hunting (Spowart 2003). Elk range north to Crosier Mountain and Glen Haven and east to Drake and Bobcat Gulch and the vicinity of the Meadowdale Ranch (Bear 1989, Larkins 1997, Spowart 2003). Elk also use Storm Mountain, Jug Gulch, Bear Gulch, and the Pole Hill-Nixon Park areas (Spowart 2003). Other elk populations also use areas east of the Estes Valley (Bear 1989); the extent to which Rocky Mountain National Park / Estes Valley elk mix with these populations is not known, but it is estimated that at least 1,000 elk from the RMNP/EV population spend several months per winter in these areas (Spowart 2003).

Primary summer range areas in the park are at higher elevations in alpine and subalpine habitat, and in the Kawuneeche Valley on the west side of the park (Figure 1.1). Outside the park, elk summer in the Twin Sisters, Lion Gulch, Pierson Park, Lake Pasture, Big Elk Park, and Big Elk Meadows areas (Larkins 1997, George 2003). At least 10% to 15% of the Rocky Mountain National Park / Estes Valley population has been documented to summer on the winter range. Recent park surveys indicate that during summer, at least 100 to 200 animals stay on the park winter range areas, and as many as 550 animals stay on town winter range areas. The only large group of elk (> 300 animals) that summer on the winter range generally uses the Meadowdale Ranch and 18-hole golf course on the east end of Estes Park. This group has stayed in this area since at least the 1970s (Stevens 1980a), although their numbers have increased over the last 30 years.

In the fall of 2002, three elk that were radio-collared in the park were observed further east, just west of the town of Loveland, along with a much larger group of elk than the resident population in that area. This coincided with much smaller population estimates in the Estes Valley than previous years, suggesting that 200 to 300 elk that normally wintered in the Estes Valley moved eastward. Following the 2002-2003 winter, two of the radio-collared elk returned to summer in the park, while the third remained with the population near Loveland. Since that time, the size of the Loveland population has remained higher than it was prior to 2001, while the size of the Rocky Mountain National Park / Estes Valley population estimates have been lower, particularly for the town subpopulation. The cause of any potential shift eastward is unknown, although suggestions have included effects of drought, several significant snowfall events, and limited forage due to high elk densities in the Estes Valley. It is unknown whether some or all of these elk still summer in the park and whether recent shifts are temporary or long term.

Reproduction

The elk breeding season generally begins in late August and extends through November, with a peak in breeding behavior from mid-September to mid-October. Cow elk may become sexually mature as yearlings, although the proportion that successfully breeds is highly variable. Nutritional and environmental factors influence yearling cow pregnancy rates; winter severity and population density can be important factors (Houston 1982). Cow elk between ages 3.5 years and 7.5 years are generally the major contributors to the productivity of elk populations (summarized in Raedeke et al. 2002). In cows more than three years of age, body condition and environmental stresses influence reproductive success (Raedeke et al. 2002).

While yearling bulls are physiologically capable of breeding, behavioral interactions generally preclude this behavior. Bulls up to three years of age are unable to compete successfully against mature bulls. Older bulls tending harems usually prevent access to cows in estrus through intimidation and by physically driving yearling bulls away (Squibb 1985). Because of social

structure, bulls do not generally manage to acquire harems until their third or fourth year (Armstrong 1987). The largest bulls in prime condition (usually six to eight years old) are the most successful at gathering harems and fending off challengers. The most aggressive bulls will assemble harems that are typically 5 to 15 cows, but harems can be larger. One bull will breed many females.

During the rut, mature bulls fend off rivals with chases and sparring matches, and herd cows to keep them in a guardable harem. Bulls bugle both to warn other males and to attract females. They also engage in other activities such as urine spraying, wallowing, and thrashing vegetation with antlers to gain attention.

Calves are typically born in late May and early June. Calving is known to occur in the Estes Valley, both in the park and in Estes Park, along migration routes to the alpine summering areas, and in the Kawuneeche Valley. When calving, cows seek solitude in forest or shrub cover. While calves are mobile within hours of birth, mothers often leave their newborns hidden in cover while they forage. Calves develop quickly and are usually weaned by late summer (Armstrong 1987).

Survival and Mortality

The largest source of mortality for adult elk in the population is hunting; however, elk that spend winter in the park or Estes Park are not affected by hunting unless they leave to use adjacent U.S. Forest Service or private lands where landowners allow hunting. This can occur, particularly in response to heavy snowstorms.

Lubow et al. estimated survival rates from 1965 to 2001 in the park and 1978 to 2001 in town (2002). During these periods, bull survival increased from 52% to 79% in the park, but remained constant at 42 % in town. Low but increasing male survival in the park indicate that these individuals are also subject to harvest at some times, but vulnerability has declined over time. Lubow found that adult female survival was about 91% for both park and town and concluded that harvest did not appear to have a differential effect on cow survival in the park versus town subpopulations. However, in the past several years, cow harvest has increased, so this may no longer be the case.

A calf mortality study conducted in Rocky Mountain National Park and the Estes Valley between 1979 and 1982 found that malnutrition was the most significant source of mortality (~35%), followed by hunting (~23%), predation by coyotes (~17%), and disease (~12%) (Bear 1989). Most death from malnutrition occurred in the first few weeks after birth, and was attributed to cows being in poor condition due to weather or resource limitations. As population sizes and densities increased from 1965 to 2001, calf survival to eight months of age declined in both park and town (Lubow et al 2002). Calf survival to 20 months also declined strongly in the park as elk density increased, and was present but less apparent in town. In 2001, calf survival to eight months was 35% and 88% in the park and town, respectively. Survival to 20 months was 24% in the park and 73% in the town.

Habitat

Winter Range

Elk use Moraine Park / Beaver Meadows and Horseshoe Park as winter range, where they forage in the meadows and bed down in nearby forested areas. The area consists of low-lying valleys

created by glacial moraines that have formed large, open meadow areas east of the Continental Divide. These valleys lie on an east-west traverse to form continuous elk habitat with the town of Estes Park. Herbaceous wetlands within these areas of the park have a high component of sedges (*Carex spp.*), juncus, and Canadian reed-grass (*Calamagrostis canadensis*). These understory species in the riparian shrub community are heavily grazed by elk. They make up a significant portion, though not a majority, of these areas. The terrain of Moraine Park (8,140 feet) consists of a large, open meadow/grassland area that is bordered by lodgepole pine (*Pinus contorta*) and Douglas-fir (*Pseudotsuga menziesii*) on north facing slopes and ponderosa pine (*Pinus ponderosa*) on south facing slopes. The Big Thompson River runs west to east through the middle of Moraine Park, with numerous old/abandoned and active channels in the flat, eastern grassland areas. The river is bordered by mountain willow (*Salix monticola*), flat-leaved willow (*Salix planifolia*), Geyer's willow (*Salix geyeriana*), mountain birch (*Betula occidentalis*), and alder (*Alnus spp.*).

To the north of Moraine Park lies Beaver Meadows, which consists of grasslands and upland shrubs that are interspersed with patches of ponderosa pine. It is transected by Beaver Brook, a small tributary to the Big Thompson River, which supports wetland species similar to those found in Moraine Park. The grassland areas of Moraine Park / Beaver Meadows consist primarily of Parry's oatgrass (*Danthonia parryi*) and long-haired needlegrass (*Stipa comata*). Moraine Park and Beaver Meadows also support intermittent stands of trembling aspen. Some of these occur in open grassland areas, while others are found on forested slopes, where they are gradually being overtaken by conifers.

Horseshoe Park (8,589 feet) lies approximately 2.5 miles north of Moraine Park / Beaver Meadows. It is similar to Moraine Park, with most of the area consisting of grassland areas dominated by Parry's oatgrass and long-haired needlegrass. The Fall River runs west to east through Horseshoe Park, with mountain willow and flat-leaved willow dominating areas adjacent to the river. However, Horseshoe Park is narrower than Moraine Park, and the Fall River does not tend to braid into different channels as occurs in Moraine Park. Horseshoe Park also has numerous stands of trembling aspen.

Summer Range

Elk, especially those that winter in Moraine Park, use the Colorado River valley, on the west side of the park, particularly the Kawuneeche Valley, during summer and fall. The valley is characterized by extensive wet meadow areas surrounded by lodgepole pine. Riparian shrubs include mountain willow, flat-leaved willow, and mountain birch. Numerous aspen stands also occur.

Treeline occurs between 11,000 and 11,600 feet and consists of subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) interspersed with grassy openings. Summer range in alpine areas above treeline consists of numerous vegetation communities. For example, sites that are exposed to high winds and have coarse soils are characterized by moss campion (*Silene acaulis*), plant sandwort (*Arenaria obtusiloba*), Rocky Mountain nailwort (*Paronychia sessiliflora*), and dwarf clover (*Trifolium nanum*); whereas sites that have high moisture levels are dominated by Rocky Mountain sedge (*Carex scopulorum*), marsh marigold (*Caltha leptosepala*), and Parry primrose (*Primula parryi*) (Stevens 1979b). Alpine willow occurs in drainages and other wet areas.

Food Habits

Elk are adaptable animals that can switch from one forage species to another, allowing them to occupy a wide variety of habitats. Forage preferences change by season and also depend on forage availability, which varies between years based on weather conditions. Elk generally use areas that allow them to use both the food resources of open grasslands and shelter of the forest. Their digestive systems allow them to take large amounts of food into the rumen, then regurgitate and digest it while in the security of forested areas.

Elk diet in the park can encompass a wide variety of species in a wide variety of habitats. Grasses usually make up most of the diet, but woody shrub species are also important. Studies in the park indicate that winter diet generally includes 58% to 76% grasses, 8% to 16% willow, 0% to 13% upland shrub, 0% to 12% pine species, and a trace to 7% each of forbs and aspen (Monello et al. 2005). On the park winter range, Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*), bluejoint reedgrass (*Calamagrostis canadensis*), and mountain muhly (*Muhlenbergia montana*) are the most frequently consumed grasses. As the winter progresses, elk in the park increase their intake of browse species, which retain a higher nutritional value than grasses and forbs into late winter. The most common browse species consumed are willow leaves and stems, antelope bitterbrush (*Purshia tridentata*) stems, and shrubby cinquefoil (*Potentilla fruticosa*) stems (Hobbs et al. 1981).

While elk forage primarily in open areas, they also rely on forested areas for cover. Cows and bulls remain separate for much of the year, with cows favoring the security of groups while bulls focus less on security and more on food intake to maximize body size and antler growth (Geist 1982, 2002).

Elk Behavior

Because there are no major predators of elk in the Rocky Mountain National Park area (Singer et al. 2002), elk behavior and distribution is likely different than if their major predators were present because they can optimize their foraging strategies by decreasing their vigilance for predators (Laundré et al. 2001). Studies conducted in other locations showed that elk will decrease their use of areas where predators are present (Altmann 1956, Ripple et al. 2001). In the absence of an intact predator base, elk in the park and town are more sedentary than they would be under natural conditions, with large groups remaining in high-use areas for long periods. Due to their close proximity to people in the park and town, these elk have lost their natural wariness and are highly habituated, allowing people to approach very closely. These behaviors reduce the wildness of the Rocky Mountain National Park / Estes Valley population.

Elk may be found as individuals, in small groups, or in larger groups at any time of the year (Murie 1951); however typical group sizes tend to change seasonally. Elk are gregarious, and winter groups are generally the largest. In the spring, cows are often in small groups or alone when calves are born. During the summer, cows, calves, and young bulls generally occur in groups of variable size. Older bulls are often alone or in small groups. The fall mating season changes elk social structure. Older bulls join the cows, and younger animals and cow/calf groups are often smaller as each harem may be tended by one mature bull. Younger bulls sometimes band together, but some remain near the cow/calf groups and join these groups later in the season.

Body Condition and Energetics

Elk body condition varies seasonally, being highest during summer and lowest in winter (Coughenour 2002). The body condition of adult elk in the park subpopulations is lower than

would be expected in a population that is not at carrying capacity (Bender and Cook 2002). Activities associated with the rut are energetically demanding, particularly for bulls. Mature bulls eat less than usual during this period, so they enter winter with their surplus body fat depleted. Unlike bulls, cows continue to eat normally during the rut and maintain good body condition (Murie 1951, Geist 1982).

Chronic Wasting Disease

Prevalence of chronic wasting disease in elk in the region is estimated to be 0.3% to 2.1%, based on CDOW hunter harvest surveys. Prevalence in the Rocky Mountain National Park / Estes Valley population has not been determined specifically, so the regional estimate is used. There is currently no validated live test for chronic wasting disease in elk, so cases are determined only by sampling tissue from carcasses. Outside the park, prevalence of the disease is estimated based on samples collected from hunter harvest.

VEGETATION

Focal Vegetation

The impact analysis in this plan/EIS focuses on the following vegetative types (Figure 3.2):

Aspen that are located in the grasslands of the elk range. These aspen are affected by elk herbivory and are not subject to succession by conifers. They are referred to simply as aspen throughout this plan/EIS;

Willow, which is the predominant component of the riparian shrub and the subalpine and alpine shrub vegetative categories;

Bitterbrush and sagebrush upland shrubs;

Riparian and upland herbaceous; and

Subalpine and alpine herbaceous.

These vegetation types that occur on the elk range are most impacted by elk herbivory, have been most studied, and are expected to be most affected by the proposed management alternatives. Table 3.1 provides the area covered on the primary elk range by each type. Although forests make up a large portion of the primary elk range, conifer forests provide little forage for elk (Hobbs et al. 1981, Singer et al. 2002), have little effect on elk populations, are not expected to be impacted by this plan, and therefore will not be retained for further discussion.

**TABLE 3.1: ACRES OF FOCAL VEGETATION DISTRIBUTED
ON THE PRIMARY ELK RANGE**

	Total Range Acres	Winter Range Acres	Summer Range Acres
Non-conifer-associated aspen	545	400	145
Riparian shrub (including willow)	1,854	655	1199
Subalpine and alpine shrub (including willow)	2,238	2	2,236
Riparian herbaceous	2,614	514	2,100
Upland herbaceous	1,619	1,434	185
Bitterbrush and sagebrush upland shrub	368	349	19
Subalpine and alpine herbaceous	9,581	11	9,570

While this plan references various research results based on exclosure of elk from areas of the elk range, it is important to note that because elk and mule deer are native to Rocky Mountain National Park, some level of herbivory effects is expected. This research is presented to show the potential for vegetation response in the absence of herbivory.

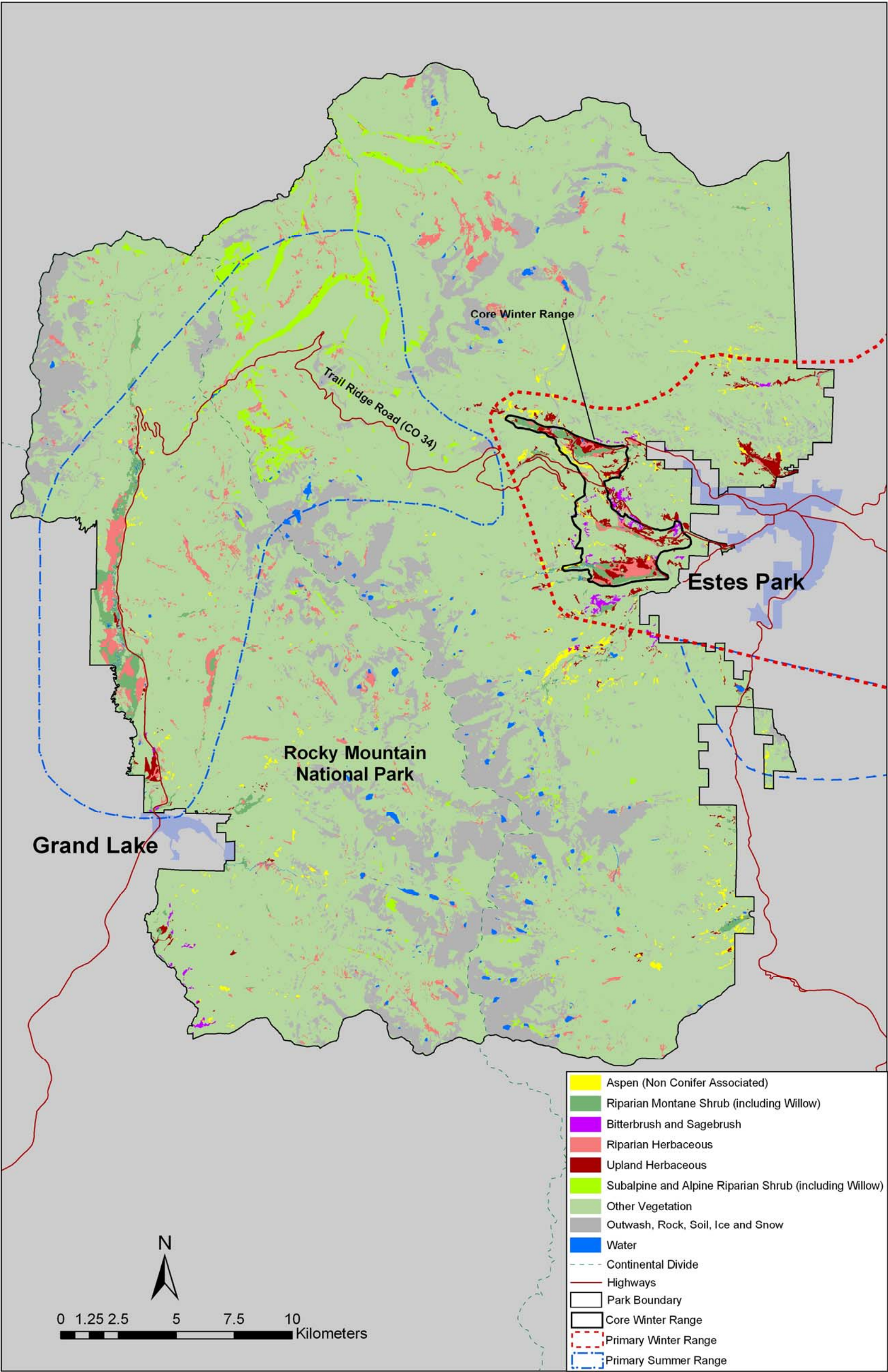


FIGURE 3.2: FOCAL VEGETATION TYPES IN ROCKY MOUNTAIN NATIONAL PARK

Aspen

Reproduction

Aspen trees that are connected by their roots are referred to as a clone, and almost all aspen stands that have been studied in the western U.S. are made up of a single clone or mosaic of clones (Shepperd and Engelby 1983, Schier 1985, Kay 1997a). Few aspen trees live more than 200 years (Jones and Schier 1985), but aspen clones are often hundreds if not thousands of years old (see also Kay 1997b). When aspen clones are lost in localized areas, the loss may indicate that the system is outside its range of natural variability.

Aspen almost always reproduce asexually (Shepperd and Engelby 1983, Schier 1985). Asexual, or vegetative, reproduction is when the interconnected roots give rise to suckers that eventually become aspen trees. Periodic disturbances such as fire, avalanche, beaver activity, and elk browsing are necessary for aspen to regenerate vegetatively. The disturbance promotes the growth of new suckers, and the existing trees resume growth (Schier 1985). Deteriorating, overmature aspen clones often fail to regenerate because they have no new suckering and tree growth that would increase vitality of the clone, but rather they maintain existing trees over a shrinking root system (Schier 1975).

Aspen establishment can also occur through sexual reproduction by means of seeds. This type of reproduction is thought to be rare in the western United States because seedlings can survive only a narrow range of conditions, which have not been commonly present in this area for thousands of years (Shepperd and Engelby 1983, McDonough 1985).

Aspen addressed in the elk plan do not require fire to regenerate (W. Baker et al. 1997); light surface burns can stimulate sucker production by allowing more solar radiation to warm the mineral soil (Romme et al. 1995). Prescribed fire is currently not being used as a tool to stimulate aspen growth because no aspen suckers less than 6 feet can escape elk herbivory on the elk winter range, and elk herbivory in the winter range has almost eliminated the ability of those aspen to regenerate into trees (Olmsted 1979 and 1997, W. Baker et al. 1997, Suzuki et al. 1999).

Distribution and Historical Establishment

Approximately 5% of aspen in the park are located on the elk winter range or in Kawuneeche Valley and have been negatively affected by elk browsing (Suzuki et al. 1999); approximately 370 acres are found on the winter range and 130 acres on the summer range. The aspen discussed in this plan are those that are considered to be non-conifer associated and will be referred to as aspen in this document.

The distribution and abundance of aspen have declined during the 20th century (W. Baker et al. 1997, Peinetti et al. 2001). This decline is significant because aspen communities provide habitat for a disproportionately large number of plant and animal species in the park (Mueggler 1985, Connor 1993, Turchi et al. 1994, Simonson et al. 2001). Loss of aspen plants or suppression of their growth often leads to a localized loss of plant and animal species (Nietvelt 2001, Dobkin et al. 2002).

The decline in aspen has been documented in other areas across the western United States over the last 100 to 200 years (Bartos 2001). Although most of the declines are attributed to a lack of fire, which allows conifers to shade out and eliminate aspen stands, elk have also been identified as a primary factor inhibiting aspen regeneration and growth in those areas (White et al. 1998, Bartos 2001, Rolf 2001, Romme et al. 2001).

It is not yet known when the aspen in the park were established or how the distribution of aspen fluctuated prior to the last 250 years in the park. In addition, when known, the 19th century distribution of aspen cannot be assumed to be representative of a long-term, static state. There is no sound evidence that aspen were present on the elk winter range prior to elk extirpation by 1880 (Monello et al. 2005). Research was conducted to age various aspen trees on the elk winter range, but none of the resulting estimated dates were prior to elk extirpation (W. Baker et al. 1997, Olmsted 1979). However, the results could also be a function of aspen longevity, which typically does not extend beyond 100 to 150 years of age (Jones and Schier 1985).

The best available information indicates that aspen have been present in most of their current locations for hundreds of years (Monello et al. 2005). Aspen are generally a clonal species that have not reproduced by seed in the western U.S. for hundreds of years (Romme et al. 2001), and some studies at Yellowstone National Park find at least a small percentage of aspen establishment prior to 1880 (Romme et al. 1995, Ripple and Larsen 2000). Additionally, studies have documented aspen establishment during periods when large elk populations of over five hundred animals were present (Olmsted 1979, W. Baker et al. 1997), such as before 1880. Modeling found that aspen can regenerate, depending on the elk density and amount of time elk spent feeding in the aspen stands (Weisberg and Coughenour 2003).

However, there may have been no aspen clones in the park on the elk winter range prior to elk extirpation. The lack of elk herbivory, along with fires that were common during the 1880s, could have provided favorable conditions for establishment of aspen in the elk range by seed (Rowdabaugh 1978, Veblen and Lorenz 1991, Mast et al. 1998, Veblen et al. 2000). Aspen can reproduce by seed and establish new aspen stands, especially following fires (Kay 1993, Quinn and Wu 2001). This type of reproduction has been documented in the western United States in association with large fire events (Romme et al. 1995, Romme et al. 2001). In addition, modeling found that almost any population size of elk in the park can prevent aspen cohort establishment, and that current stands are primarily a result of aspen expansion while elk were extirpated from the area (Coughenour 2002).

Debate about aspen establishment is not isolated to Rocky Mountain National Park (Monello et al. 2005). However, until further research can refute the hypothesis that the presence of aspen is not a result of elk extirpation, the park plans to manage aspen on the elk winter range as a natural component in those areas.

Herbivory

In Rocky Mountain National Park, the annual offtake (consumption of biomass) of aspen in the core winter range is 18% (Zeigenfuss n.d.). This level of herbivory has prevented aspen suckers from maturing into trees capable of escaping elk herbivory (≥ 8 feet in height) on the elk range since at least 1970, as shown in Figure 3.3 (W Baker et al. 1997, Olmsted 1997, Suzuki et al. 1999, Kaye et al. 2005).

As a consequence, existing aspen trees are declining rapidly as they die of old age (Olmsted 1997, Kaye et al. 2005), resulting in overmature, deteriorating aspen stands with no small or mid-size trees to continue the vitality of the stands. Furthermore, a 42% reduction of large trees (Olmsted 1997) and a 30% reduction of growth in the aspen stands throughout the park elk range (Kaye et al. 2005) occurred between 1975-76 and 1995-96.

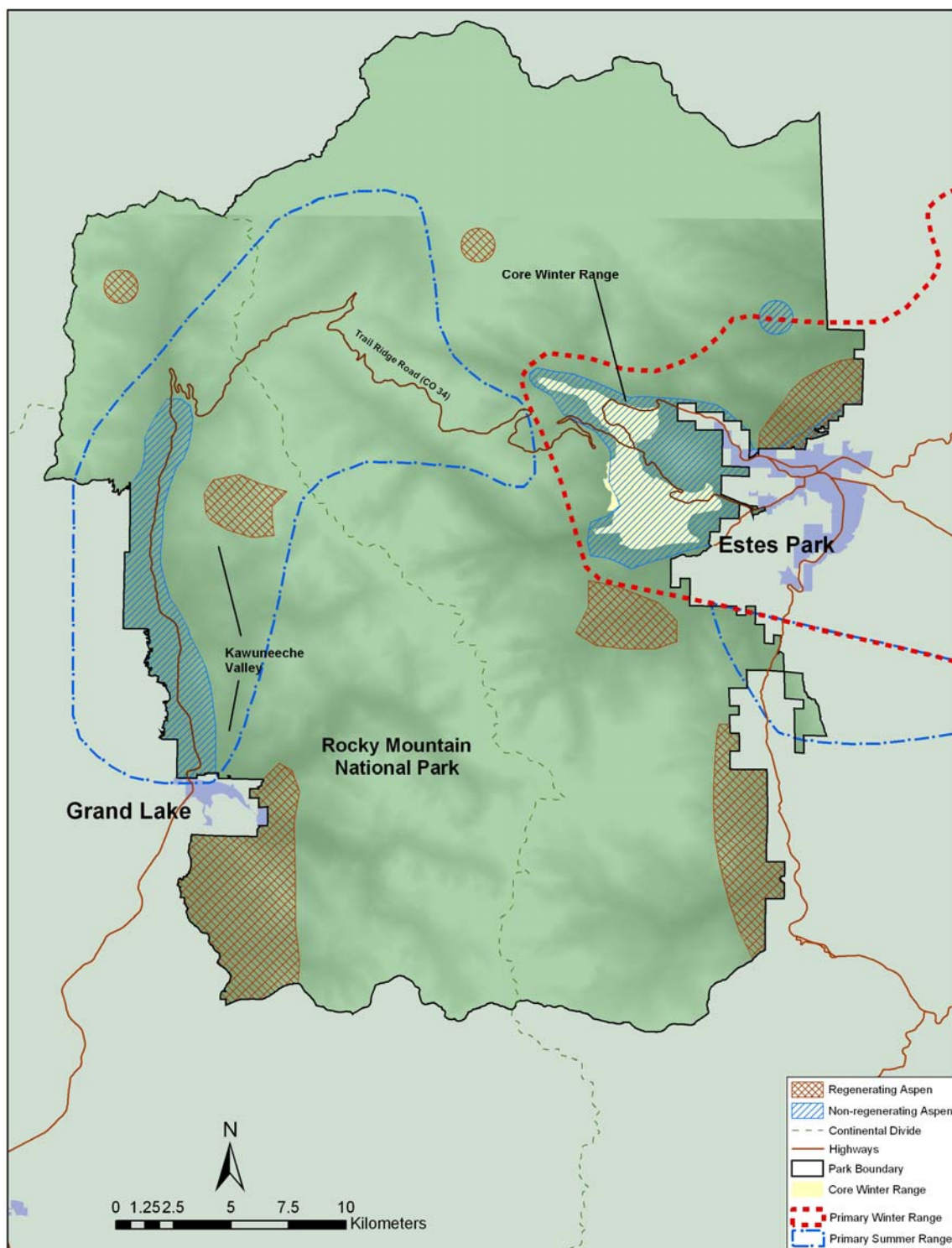


FIGURE 3.3: ASPEN REGENERATION

Research supports the hypothesis that elk numbers and distribution both directly affect aspen regeneration in the park, although it may be impossible to know which is a more important predictor of aspen utilization rates (W Baker et al. 1997). For example, aspen stands only produced a new cohort (trees of the same age) of trees in the park when the elk population was less than 600 animals (W Baker et al. 1997). Also, only those aspen stands with less than a 50% utilization rate by elk can escape herbivory and successfully establish a new cohort (Olmsted 1979). In addition, elk densities may need to be 26 elk per square mile or lower to allow aspen on the winter range in the park to regenerate (Weisberg and Coughenour 2003).

An analysis of two 35-year aspen exclosures on the elk winter range showed that aspen can successfully regenerate and contain multiple age classes of aspen. The ratio of live to dead trees was twice as high for stands inside the exclosures. Stocking rates inside and outside the exclosures averaged 637,000 and 122,980 suckers per square mile, respectively, and there are also more live branches and fewer dead branches inside versus outside the exclosures (W Baker et al. 1997).

For most people, perhaps the most obvious impact of elk herbivory is the stripping of bark off live trees. The nutritional value of bark is unknown. However, aspen barking by elk is not believed to be related to food shortages; aspen were barked when only 350 elk were estimated to be on the winter range. Bark stripping does not usually kill aspen, but it can create inoculation sites for pathogens that lead to aspen mortality (Hinds 1985). Therefore, bark stripping is not nearly as important as the tree death and lack of regeneration caused by elk at current numbers and densities.

Montane Willow

The montane zone extends below an elevation of approximately 9,500 feet. The following discussion pertains to willow within this zone.

Reproduction

Willows in Rocky Mountain National Park establish themselves on three principal landforms that provide the necessary conditions of bare, moist mineral soil: point bars along stream channels; abandoned, draining beaver ponds; and abandoned channels that function as oxbows (Cooper et al. 2003). The latter two landforms are both associated with the presence of beaver in an area, suggesting that beaver are important in both asexual and sexual reproduction used by willow for establishment.

Sexual reproduction is accomplished through production and successful germination and establishment of seeds. Willow seeds are only viable for a few days and can only take root in wet areas with unvegetated or disturbed soils with good light availability (Cottrell 1993, Cottrell 1995). Willow seeds have limited aerial or water dispersal ability and low entrapment rates, which compromises their establishment success. In addition, seedling growth is slow, and their roots may take 3 or 4 growing seasons to reach groundwater level, making them susceptible to drought, desiccation, and disturbance (Cooper et al. 2003).

Even though reproduction by seed is currently the most common method of willow establishment in Rocky Mountain National Park, current browsing levels by elk on the winter range have greatly decreased this ability by inhibiting seed production, dispersal, and survival. The condition of willow stems is so poor due to heavy elk browsing that many areas in Moraine Park lack seed-producing willows and receive very low seed rain densities. In some areas with less elk use, the presence of surviving, old, tall willow plants provides better seed production, as in the western

portions of Moraine Park compared to the eastern portions, as shown in Figure 3.4 (Gage and Cooper 2003 in Cooper et al. 2003). Figure 3.4 shows seed rain in Horseshoe Park (Gage and Cooper 2003 in Cooper et al. 2003).

Asexual, or vegetative, reproduction occurs when existing willow roots or a willow stem cut by beaver gives rise to new shoots that become new plants. Shoots from the roots of a willow are important because they allow existing willow plants and root systems to maintain themselves for periods of 100 years or longer. Beaver cuttings also allow willows to colonize areas that are suitable for willow growth but not seedling establishment; this effect may be important on a landscape scale. In addition, beaver ponds drown some plants but allow opportunities for new colonization for other plants like willow (Cooper et al. 2000, B. Baker et al. 2005). Beaver can also enhance willow establishment, survival, and dominance in the landscape because of the competitive advantage willow have in riparian areas (B. Baker et al. 1992, B. Baker et al. 2005). Drying wetlands may be invaded by non-wetland species, causing changes in plant community composition in riparian areas (ter Brack and Wiertz 1994, Vasander et al. 1997, Minkinen et al. 1999). Little to no establishment of willows in the park occurs asexually due to little beaver activity in the area (Cooper et al. 2003).

As discussed in the “Water Resources” section, the loss of beaver dams and subsequent degradation of hydrologic conditions needed for willow establishment and survival may prevent willows protected from elk browsing from responding well until favorable hydrologic conditions are restored (B. Baker et al. 2005). In addition, once willow areas are converted to herbaceous plants, willow seeds or cuttings cannot compete and reestablish in those areas until beavers change the hydrology and create bare soil areas favorable to willow establishment (Cooper 2001).

Another factor impacting willow establishment in the Kawuneeche Valley on the elk summer range is the Grand Ditch water diversion (see “Water Resources” section). The Grand Ditch reduces the peak flows of water into the Colorado River and Kawuneeche Valley, lowers the groundwater, and reduces the soil water content on gravel bars, thereby lowering the required bare, moist soil needed for willow establishment (Cooper et al. 2000).

The fire management plan calls for the postponement of burns in willow until they can be adequately protected from elk herbivory as outlined in this plan. Park managers believe that fires in montane riparian willow of the park historically occurred every 35 to 200+ years due to the wet conditions often present, but when they did occur they were stand replacing. Currently, with the altered hydrologic and herbivory conditions and the associated increase in dying willows and accumulations of dry woody material, conditions are more conducive to fire. Although not necessary for willow regeneration, it has been suggested that the use of fire or mechanical removals could speed the process (B. Baker 2005).

Distribution

Willow is the dominant woody shrub in almost all riparian areas in Rocky Mountain National Park. There are primarily three species of willow on the elk winter range: Geyer’s willow, mountain willow, and flat-leaved willow (Zeigenfuss et al. 2002). Park-wide, mountain willow and flat-leaved willow tend to be co-dominant below 2,900 m (9,500 feet), while flat-leaved willow dominates above this elevation (Cottrell 1995).

The distribution and abundance of willow within the current boundaries of Rocky Mountain National Park has been reduced several times since settlement both by human disturbance and elk herbivory. Modeling suggests that willow cover did not exhibit an increase when elk were extirpated by the 1880s (Weisberg and Coughenour 2003).

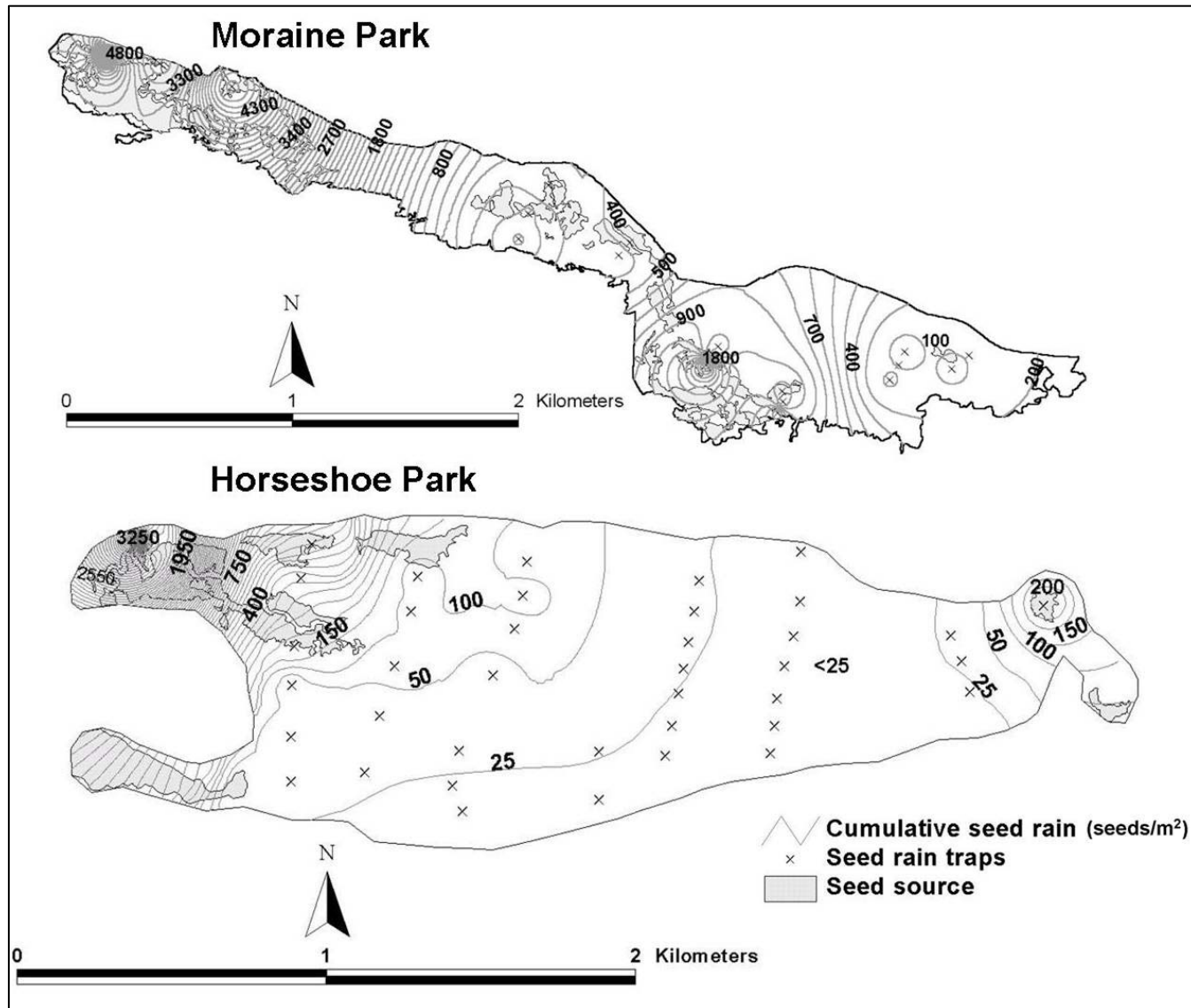


FIGURE 3.4: MORAINE PARK AND HORSESHOE PARK SEED RAIN

Reports from the late 19th century suggest that Moraine Park had more extensive willow and riparian shrub cover at that time than it did in the 1930s and 1940s, probably because many areas were drained and cut down for haying purposes as the area was settled (Gysel 1960). In addition, although the previously mentioned development in elk winter and summer range areas was not studied for its specific effects on willow, it is believed that there was some reduction in willow due to development.

Over the past 50 to 60 years, riparian shrub cover, assumed to primarily be willow, has declined by approximately 20% in Moraine Park and Horseshoe Park and is being replaced by herbaceous communities. Willow declines in Moraine Park are visibly correlated to a 69% reduction in surface water (see “Water Resources” section), caused by a greater-than-90% decline of the area’s beaver population since 1940 (Packard 1947, Peinetti et al. 2001, Zeigenfuss et al. 2002, and see “Other Wildlife” section). Although not as strongly linked, willow declines in Horseshoe Park can also likely be attributed to a 47% decrease in surface water and 90% decline in the beaver population (Packard 1947, Peinetti et al. 2001, Zeigenfuss et al. 2002).

Willow declines in Horseshoe Park are largely due to the Lawn Lake Flood (see “Water Resources” section; Peinetti et al. 2001), which created a new lake directly upstream from the confluence of Roaring Brook and Fall River. Existing willow in these areas were either destroyed by the alluvial fan created by the deposited debris or flooded out by the new lake, and some willows in downstream areas were directly removed by flood waters (Peinetti et al. 2001).

Park staff and researchers have anecdotally noticed a decline in willow in a trend similar to that on the primary winter range, especially over the past 10 years. Although no studies have been conducted to separate out elk from moose herbivory impacts, elk occur in larger numbers, are more sedentary in more vulnerable willow patches, and browse in spring, which is a more critical time for willow as they put on growth for the year (Cooper and Westbrook 2005).

Herbivory

Willows have developed two primary defenses against the effects of browsing: first, they exhibit rapid vertical growth rates that extend growth beyond the height of browsing (Bryant et al. 1983); and second, willow can produce defense compounds that make them less palatable to large ungulates (Singer et al. 1994). However, neither defense is likely to be effective if ungulate consumption levels are too great, especially if intense herbivory is combined with beaver activity or poor site conditions (Monello et al. 2005).

Willow growth and height in the intermountain west is often determined by large ungulate and beaver browsing (Singer et al. 1994), as well as site conditions such as soil type, length of growing season, nutrient concentrations, and water table height (Cottrell 1995, Peinetti 2000). Elk can directly decrease willow growth and size (Singer et al. 2002), and indirectly reduce willow by out-competing and reducing beaver (see “Other Wildlife” section), which maintain surface and groundwater levels as well as establishment sites favorable to willow (Cooper et al. 2003, and see “Water Resources” section).

These direct and indirect elk affects have resulted in a transition of tall willow to short willow and in suppression of short willow plants from becoming tall willow over the last 60 years in Moraine Park and Horseshoe Park (Peinetti et al. 2001, B. Baker et al. 2005), as shown in Figure 3.5. Willow may be short because they are newly established, elk may rub their antlers tearing down tall willow, or beaver may have cut down tall willow for food. The interaction of beaver and current elk herbivory levels strongly suppress willow growth (B. Baker et al. 2003), because once beaver cut down willow, the new regrowth is more suitable as elk forage since all stems are in reach (B. Baker et al. 2005).

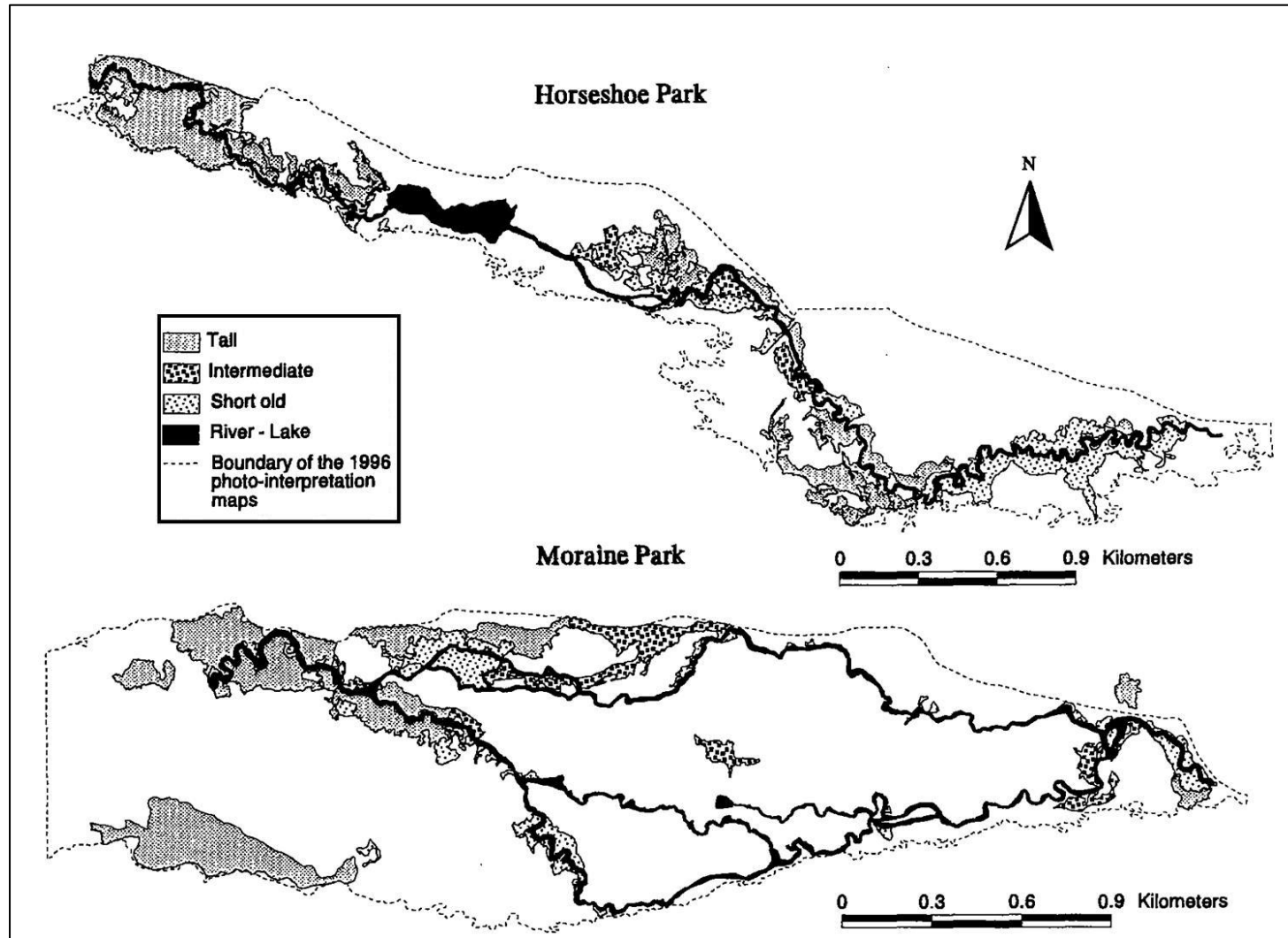


FIGURE 3.5: MORAINE PARK AND HORSESHOE PARK TALL-TO-SHORT WILLOW CONVERSION

In addition, short willow can be old or young plants (Cooper et al. 2003) that are simply shorter than their tall willow counterparts of the same species. These shorter willows are suppressed by current elk browsing levels; currently few to no willow plants grow beyond 3 feet tall (Peinetti et al. 2001, Zeigenfuss et al. 2002, Cooper et al. 2003).

Patches of tall willow still exhibit significant reproduction in Endovalley, Moraine Park, and Kawuneeche Valley; however, no young willows grow into tall willow. This is an unstable condition because even if the tall willow can withstand elk herbivory pressures, they will be less able to survive other natural stresses such as fire, disease, river bank erosion, and beaver herbivory (Cooper 2001).

The following information presents the average consumption rates and production of willow on the winter range. In Rocky Mountain National Park, elk were observed in riparian willow 7% of the time, which suffered an average annual 33% offtake (consumption of shrub production) (Schoenecker et al. 2004). Research has focused on elk winter range willow rather than summer range willow. Based on researcher and park staff observations, primary summer range willow cover is declining.

Willow have declined approximately 20% on the primary winter range (Singer et al. 2002, Zeigenfuss et al. 2002, Peinetti et al. 2001). One exclosure site in Beaver Meadows illustrates elk herbivory impacts. After 35 years, willow volume and height were 98% greater inside the exclosure than outside (Schoenecker et al. 2002). On average, willow sites had 66% lower willow production in grazed versus exclosed plots after four years (Schoenecker et al. 2004). Herbivory reduced height, canopy size, and litter biomass of willows, leading to 64% less nitrogen yield in grazed plots (Schoenecker et al. 2004).

Willow growth and size were optimized at an approximate elk consumption rate of 21% and negatively affected at 37%. Optimal willow growth refers to the maximum observed willow production in the presence of elk herbivory, which was greater than ungrazed willows. Negative willow growth represents a 40% decline in most components of willow growth from maximum growth levels. Elk densities greater than or equal to 83 elk per square mile generally resulted in a 40% decline in willow size and growth parameters (Singer et al. 2002). However, as discussed in the "Elk" section, willow consumption rates, elk densities, and willow production vary greatly across the winter range (Peinetti et al. 2001, Singer et al. 2002, Zeigenfuss et al. 2002).

The effects of elk herbivory on willow production, which is the new biomass grown by the plant each year, have not been conclusively shown. One study found elk significantly reduced willow production after four years of excluding grazing (Zeigenfuss et al. 2002), but another found that while browsed plants were smaller, there was similar overall biomass production because the willow produced longer, thicker shoots in the lower levels of the plant canopy (Peinetti et al. 2001, B. Baker et al. 2005).

Non-streamside willows showed a decrease in the ability of roots to reach groundwater sources because the plants allocate more of their carbon to stems and leaves than to roots in response to high levels of herbivory (Menezes et al. 2002, Peinetti et al. 2001). Despite herbivory, in areas where water is flowing in streams, the roots of established willow plants three years of age or older can easily reach the groundwater, which generally does not fall below 3 feet during the growing season (Zeigenfuss et al. 2002, Cooper et al. 2003, Menezes et al. 2002). However, many researchers believe that the effect of shallower water tables are minimal when compared to elk browsing effects (Singer et al. 2002, Zeigenfuss et al. 2002) because many stream-side plants with excellent water availability are in poor condition due to the effects of elk browsing (Peinetti et al. 2001, Zeigenfuss et al. 2002, Cooper et al. 2003).

Elk have reduced beaver populations by out-competing beaver for food resources (particularly

willow), which in turn reduces surface and groundwater levels and establishment sites, which decreases willow. Large expanses of willow have died where streams have become totally dry and water tables have apparently experienced dramatic decreases, suggesting that willow growth and survival in the park primarily depend on ground water from streams and snowmelt instead of rainfall (Alstad et al. 1999). Many stream channels in Moraine Park that were filled with water and bordered by live willow in 1937 are now dry with large, dead willow on the old stream banks.

Bitterbrush and Sagebrush Upland Shrubs

Reproduction

No research has been conducted specifically on the factors affecting upland shrub reproduction or recruitment in Rocky Mountain National Park. However, it is known that natural disturbances such as fire and browsing can greatly affect the growth and reproduction of both bitterbrush and sagebrush. Seeds are the primary method of reproduction of bitterbrush (Daubenmire and Daubenmire 1968; West 1968) and sagebrush (Ratzlaff and Anderson 1995) following fire.

Bitterbrush has a greater tolerance to fire because it can resprout from previously existing plants if the fire is not too intense (Blaisdell and Mueggler 1956). Conversely, sagebrush plants are easily killed by fire and can have trouble reestablishing because they only reproduce by seed (Kershaw et al. 1998, Wambolt 1998, Wambolt et al. 2001). Recovery rates for both species following fire can range from just a few years resulting in a rejuvenated shrub community to over 30 years and a greatly deteriorated community (Bunting et al. 1985, Wambolt et al. 2001).

The park's fire management plan calls for the postponement of burns in upland shrubs until they can be adequately protected from elk herbivory as outlined in this plan. The future use of fire in these areas will not be used for the promotion of upland shrub regeneration, but rather for the attainment of other community protection and ecological restoration objectives as detailed in the fire management plan.

Distribution

Bitterbrush and sagebrush are found on arid plains and slopes throughout the Rocky Mountains. The natural or historic (pre-1860) coverage of bitterbrush and sagebrush on the winter range in Rocky Mountain National Park is unknown. By the time shrub communities in the park were studied in the 1930s, they had been significantly altered. Market hunting during the 1860s and 1870s significantly reduced elk and deer numbers, likely allowing upland shrubs to expand, but fires in ponderosa pine forests during the 19th century (Veblen et al. 2000, Ehle 2001) and expanding deer population in the early 1900s (Stevens 1980a) may have also greatly decreased shrub abundance.

By the 1930s, managers in the park concluded that the expanding deer population was having a large, negative effect on upland shrubs (summarized in Grater 1945). Despite the decline in deer starting in the 1940s, which was further facilitated by National Park Service reduction programs, sagebrush apparently continued to decline (Gysel 1960), but no quantitative data [related to distribution](#) were ever collected on upland shrub population trends.

Herbivory

As discussed in the "Other Wildlife" section, upland shrubs are an important diet component for deer in the park, and to a lesser extent elk, because they maintain higher protein levels than grasses (Kufeld et al. 1973, Stevens 1980a, Hobbs et al. 1981). Between 1968 and 1992, elk use

increased while deer use decreased in upland shrub communities (Zeigenfuss et al. 1999, Stevens 1980a). Small mammals have also been found to feed extensively on bitterbrush seeds (Martin et al. 1951) and can have a large, detrimental effect on bitterbrush recruitment (Clements and Young 1996).

One study observed elk in upland shrub communities 10% of the time and found a 12% annual consumption of upland shrub biomass (Schoenecker et al. 2004). From 2001 to 2002, there was 21% total shrub consumption and 49% leader use in bitterbrush (Nescavil 2003). Also, based on two exclosures, nitrogen yields in upland sagebrush were 70% less than in ungrazed sites (Singer and Schoenecker 2003). This level of herbivory has negatively affected total estimated annual shrub production in 2002 (Nescavil 2003).

Excluding elk and deer for four years had no effect on bitterbrush production or size (Zeigenfuss et al. 2002); however, after 25 years, bitterbrush increased 12% to 15% where it was not initially present and 31% to 37% where it was initially present (Gysel 1960). After 35 years, upland shrub (sagebrush) current annual growth was 67% higher inside exclosures versus outside (Schoenecker et al. 2002). Bitterbrush is more resistant to browsing than sagebrush due to plasticity in growth rates and resource allocation traits (Bilbrough and Richards 1993).

If large ungulate herbivory follows fire events, it can often result in long-term or permanent shrub loss (Wambolt et al. 2001). Herbivory causes small, long-term costs to the shrubs, which reduce their capacity for growth. Conversely, fire is a one-time event that may decrease the net energy available to the shrub.

In Rocky Mountain National Park, total shrub canopy area and volume can recover after a burn in the absence of browsing or if the levels of browsing are less than the current high levels (Nescavil 2003). Resprouting of bitterbrush was observed in all sites after prescribed fire was applied in the park, but bitterbrush size declined after the first and second year and production declined after the second year. This suggests that additional plant mortality took place during the first year after the fires (Zeigenfuss et al. 2002). Nesvacil and Olmsted (2002) found that decreases in bitterbrush canopy area, volume, and estimated annual production continued six and seven years post-burn, while total shrub canopy area, volume, and annual production only differed due to grazing. This suggests that bitterbrush can resprout adequately after burning, but the current levels of herbivory in Rocky Mountain National Park are impeding regeneration (Nesvacil and Olmsted 2002) and altering post-fire successional patterns (Nesvacil 2003).

Therefore, on May 13, 2003, a memorandum was included in the management files that states:

Until management actions have been taken to change the population and distribution of elk in the park, the use of prescribed fire in areas with antelope bitterbrush, rabbit brush, sage brush, and wax currant will result in unusually high levels of herbivory post-fire, leading to a net loss of upland shrub habitat. ...[P]lans to utilize prescribed fire as a tool to reduce fuel and reintroduce fire to the ecosystem will be postponed to a later date, presumably until actions have been taken to manage the elk population and distribution. When and if elk densities are lowered, the park will continue to pursue scientific research regarding the effects of elk herbivory following any prescribed fire treatments.

Riparian and Upland Herbaceous Plants

Reproduction

By definition, herbaceous plants have no woody components; therefore, they do not persist through winter. The diversity of the herbaceous plants comprising the elk range and their reproduction methods is beyond the scope of this plan to detail. However, under normal conditions, a stand-replacing fire in upland herbaceous communities is expected every 0 to 35 years (NPS 2004a) and expected by park managers in riparian herbaceous communities every 35 to 200+ years.

Distribution

Fire suppression may allow ponderosa pine trees to expand into and overtake some of the upland meadows that make up the core of the elk winter range and their primary forage base. This could potentially lead to a significant decrease in elk forage, but no formal research has been conducted on this subject, and historic and current photographs indicate this is not occurring to any appreciable extent (Veblen and Lorenz 1991). Historic and current photographs do show that stands of ponderosa pine are much denser, and it appears that they may now occupy former meadows; however, this does not appear to be the case in the elk range.

Herbivory

Annual herbaceous offtake rates are reported to be 55% in riparian willow and 60% in upland shrub communities, with most offtake occurring in summer and winter, respectively (Singer et al. 2002). Mountain bunchgrass steppe and mixed prairie communities, the most comparative systems to the park, can withstand offtake rates of 40% but not 60%. Therefore, the consumption rates in the park are extremely high and, based on evidence from other areas, may alter herbaceous communities (Singer et al. 2002). Herbaceous plants in willow communities may be particularly vulnerable because the majority of grazing is occurring during the growing season (Augustine and McNaughton 1998). However, Singer et al. (2002) has shown herbaceous consumption to be about 28% in both winter and summer.

The effects of these offtake levels resulted in an 18% to 29% reduction of herbaceous production in willow communities in 1998. The production was higher in grazed versus ungrazed sites in 1994, 1995, and 1996 when precipitation was above average, suggesting that elk may have greater effects when precipitation is average or below-average (Zeigenfuss et al. 2002).

As a result of offtake levels, after 35 years, elk herbivory reduced the annual aboveground production of herbaceous vegetation by 32% (Schoenecker et al. 2004). Also, in grazed sites, nitrogen yield of upland herbaceous plants was reduced by 35% and of riparian herbaceous plants by 20% (Singer and Schoenecker 2003). Furthermore, the herbaceous root biomass was either not affected or was significantly greater in grazed versus ungrazed areas (Schoenecker et al. 2002) and may be an underground response to the decline in shrubs (Singer et al. 2002). Coughenour (2002) predicted that under current grazing pressures, root biomass would decline but eventually stabilize.

No large-scale shifts or trends in plant species abundance, biodiversity, or composition have been attributed to elk herbivory (Singer 1995, Schell and Stohlgren 1997, Stohlgren et al. 1999, Zeigenfuss et al. 1999, Zeigenfuss et al. 2002, Singer et al. 2002). In upland bitterbrush sites, ungrazed sites had a higher percent cover of prairie sage (*Artemisia ludoviciana*) and sulphur buckwheat (*Eriogonum umbellatum*) after four years (Zeigenfuss et al. 2002). In grasslands there

was an increase in the percent cover of forbs (broadleaf herbs other than grasses) and *Carex* spp. between 1968 and 1992 (Zeigenfuss et al. 1999). In willow riparian areas, grazed sites had more goldenrod species (*Solidago* spp.) and ungrazed sites had more bluebell (*Mertensia ciliata*) after four years (Zeigenfuss et al. 2002). There was an increase in grass cover on grazed versus ungrazed riparian sites after four years (Zeigenfuss et al. 1999) and a 40% decrease in grass biomass in grazed sites after 35 years (Schoenecker et al. 2002).

Subalpine and Alpine Vegetation

Distribution

The alpine tundra consists of areas above timberline at approximately 11,000 feet. The park contains over 50 square miles of alpine tundra, and elk use about 39% of it from June until October. Tundra vegetation was first described by Kiener (1939), Griggs (1956), and Willard (1963), which Stevens (1980b) summarizes into the following types: fellfields covered by cushion plants, such as mosses; alpine turf and alpine marsh, both primarily composed of sedges and wildflowers; snowbed, characterized by rushes, grasses, and wildflowers; and riparian willow areas. The distribution of these plant associations is primarily determined by physiography, snow accumulation, moisture availability, exposure, temperature, and substrate (Kiener 1939, Griggs 1956, Willard 1963, Stevens 1980b).

Herbivory

Very little work has been done in the alpine areas regarding elk herbivory and willows. Recent analysis of 12 transects in subalpine and alpine plant communities collected over varying intervals between 1971 to 1996 found that flat-leaved willow showed a 48% cover and 37% height decline, and that short-fruit willow (*Salix brachycarpa*) showed a 70% cover and 40% height decline over the 25 year period (Zeigenfuss 2005). These trends do not definitively correlate with elk herbivory; however, they do support general observations by park staff and researchers.

In addition, recent analysis of the 1971 to 1996 transects show an increase in cover and frequency of grasses and an initial decrease followed by an increase in frequency of forb species (Zeigenfuss 2005).

Two graminoid species (*Deschampsia caespitosa* and *Carex elynoides*) that Hobbs et al. (1982) identified as major elk diet components increased in cover. Although the increase in bare ground frequency is not a concern at this time, continuation of such increases could indicate problems from overgrazing and hoof action (Zeigenfuss 2005).

Exotic Species

There is currently no evidence that elk herbivory is increasing exotic plant species abundance or coverage in the park (Singer et al. 2002, Zeigenfuss et al. 1999). Landscape analyses have also failed to find evidence that grazing increases the spread of exotic plant species in the park or other Rocky Mountain grasslands, and suggests that even when at very high density, elk may actually reduce non-native plant species coverage (Stohlgren et al. 1999). However, a 54% increase in the exotic grass timothy (*Phleum pratense*) was observed in park meadows from 1968 to 1992 (Zeigenfuss et al. 2002).

AFFECTED ENVIRONMENT

Rutledge and McLendon (1996) found no evidence that Canada thistle will dominate a specific site for long periods in the absence of continued disturbance, which presumably would include high levels of elk. In response to many park staff and visitor reports, in 2003 the park reexamined a small sample of Rutledge and McLendon's study sites from 1987. After 16 years with no treatment, the ten sites increased from 12.8 acres to 69.8 acres. Although no formal studies have been conducted to quantify the cause of the increase, and by nature exotic plants increase and invade even healthy vegetation communities, the reduction of well-developed willow communities increases thistle invasion in riparian communities, and continued disturbance makes areas more vulnerable to Canada thistle invasion in the park (Rutledge and McLendon 1996).

SPECIAL STATUS SPECIES

Background

The Endangered Species Act of 1973 requires an evaluation of the effects of proposed actions on all federally listed endangered and threatened species with potential to be affected by the action. Species proposed for listing and candidate species also are evaluated. The U.S. Fish and Wildlife Service determines if a species needs protection under the Endangered Species Act and whether to classify a species as an endangered, threatened, proposed for listing, or candidate species. Endangered species are considered to be in danger of extinction throughout all or a significant portion of their range; threatened species are those likely to become endangered in the foreseeable future; species proposed for listing are in the process of being listed; and candidate species are determined to warrant protection and are being considered for listing as an endangered or threatened species. Candidate species do not have legal protection.

NPS policy also requires examination of impacts on federally listed, proposed, and candidate species as well as state-listed threatened, endangered, candidate, rare, declining, and sensitive species (NPS Management Policies Section 4.4.2.3.). The Colorado Division of Wildlife determines if a species needs legal protection within Colorado. Species listed as endangered or threatened by the state are defined in the same way as federal endangered and threatened species. The state also designates species of special concern, which have no legal protection.

Appendix D presents species with federal endangered, threatened, proposed for listing, or candidate for listing status. The U.S. Fish and Wildlife Service reviewed the list and has concurred (October 18, 2005). Species considered endangered, threatened, or of special concern by the Colorado Division of Wildlife are included in Appendix D. The sources used by the park to identify listed species also are included in Appendix D. Table 3.2 includes species that are known to occur in the park or could potentially occur in the park, and species that occur outside the park. These species could be affected by the proposed NPS actions associated with this plan and have been retained for a full evaluation of effects.

Species Retained for Further Analysis

Boreal Toad

At the time of analysis for this document, the Southern Rocky Mountain population of the boreal toad was a federal candidate for listing. As of September 29, 2005, the U.S. Fish and Wildlife Service published a notice in the Federal Register notifying the public that they were no longer considering it for listing “because it does not constitute a distinct population segment as defined by the ESA” (USFWS 2005). It remains a candidate species on the federally listed species occurring in Rocky Mountain National Park, attached as Appendix D, because the U.S. Fish and Wildlife Service has not updated the park’s list. The state of Colorado does list the toad as endangered because of large population declines from 1975 to 1990; therefore, the species is retained for further analysis. The Colorado Division of Wildlife developed a recovery plan in 1994, which was updated in 1997 and 1998 (Loeffler 1998). Rocky Mountain National Park is a signatory of the *Conservation Plan and Agreement for the Management and Recovery of the Southern Rocky Mountain Population of the Boreal Toad (Bufo boreas boreas)* (Loeffler 1998).

TABLE 3.2: SPECIAL STATUS SPECIES WITH POTENTIAL TO BE AFFECTED BY THE PLAN

Common Name	Scientific Name	Status
Boreal toad	<i>Bufo boreas boreas</i>	SE
Wood frog	<i>Rana sylvatica</i>	SSC
Greenback cutthroat trout	<i>Oncorhynchus clarki stomias</i>	FT, ST
Colorado River cutthroat trout	<i>Oncorhynchus clarki pleuriticus</i>	SSC
Greater sandhill crane	<i>Grus canadensis tabida</i>	SSC
Long-billed curlew	<i>Numenius americanus</i>	SSC
Bald eagle	<i>Haliaeetus leucocephalus</i>	ST
River otter	<i>Lutra canadensis</i>	ST
Wolverine	<i>Gulo gulo</i>	SE
Canada lynx	<i>Lynx canadensis</i>	FT, SE

Key to Status: FE = federally endangered; FT = federally threatened; FC = federal candidate for listing; SE = state endangered; ST = state threatened; SSC = state species of special concern

Boreal toads are the only high-elevation species of toad in Colorado, occurring from 2,135 to 3,660 m (7,000 to 12,000 feet). Breeding habitat includes lakes, marshes, ponds, and bogs with sunny exposures and quiet, shallow water. Boreal toad breeding does not begin until the winter snowpack starts to thaw, which ranges from May to July in toad sites in Rocky Mountain National Park (Hammerson 1999). Severe population declines are attributed to a skin disease known as chytrid fungus (*Batrachochytrium dendrobatidis*).

Twenty-one sites in the park are known to have or have historically had boreal toads. Timber Creek and Green Mountain Trail on the west side and Sheep Lakes and Horseshoe Park on the east side all historically had toads and all overlap with the elk range. Currently, only four known sites within the park have boreal toads. Only the Big Meadows site on the west side of park overlaps with primary elk summer range.

The Colorado Division of Wildlife and the park are working cooperatively to captive breed toads from the park to attempt to maintain a genetic bank from park toads and to provide toad stock for park reintroductions potentially to occur as soon as 2007.

Wood Frog

The wood frog is a state species of special concern, downlisted from threatened in 1998 by the Colorado Wildlife Commission. It is of concern to the state because its distribution is small and disjunct (Hammerson 1999) and its habitat has suffered destruction and degradation.

Wood frogs are found in riparian areas, including beaver ponds and willow thickets. They feed on worms, spiders, and insects; their predators include trout, although they generally avoid areas inhabited by trout (Hammerson 1999). In Rocky Mountain National Park, wood frogs have only been found in the Kawuneeche Valley (Corn et al. 1997), which overlaps with the elk summer

range. Therefore, any management activity that would interrupt breeding or would alter riparian habitat or water quality in the Kawuneeche Valley has the potential to impact the wood frog.

Signaled by the males begin calling, the breeding season of wood frogs starts even before the last snowfall and while ice still forms on water at night. Depending on the year, this could be in May (Hammerson 1999), with eggs being laid in May to June (Bagdonis 1971).

Greenback Cutthroat Trout

The greenback cutthroat trout is federally and state listed as a threatened species. Greenbacks are one of four trout species native to Colorado, all of which declined substantially with the settlement of Colorado in the 1800s, primarily because of land and water exploitation along with the introduction of non-native salmonid fish species such as brook trout. Salmonid fish can out-compete and hybridize with greenbacks in colder habitats because of their greater young-of-the-year size and ability to reach sexual maturation one year earlier than greenbacks (USFWS 1998). Greenback cutthroat trout spawn begins when the water temperatures reach 5°C to 8°C (USFWS 1998), which in the park can be between late May and mid July, depending on the water body. In one area of the park, emerging fry were observed in late August (Bulkley 1959).

Since the decline of greenbacks took place primarily in the 1880s, it is difficult to determine their exact historic distribution. It is believed the park was not widely inhabited by greenbacks; however, due of alterations to their native habitat, Rocky Mountain National Park is one of the few areas where the species can be adequately reintroduced, and the park has played a large role in the recovery of greenbacks.

Within the park, greenbacks are primarily found in the North Fork of the Big Thompson River, Roaring River, Fern Creek, Hidden Valley Creek, and the Wild Basin area. They seek shelter under streamside willows and other riparian vegetation. Any alteration of riparian areas or water quality has the potential to impact the greenback cutthroat trout. The U.S. Fish and Wildlife Service monitors all populations in the park, and continued reintroduction efforts are pending. The National Park Service is currently preparing the greenback cutthroat trout management plan and environmental assessment to determine the future of greenback trout restoration efforts in the park.

Colorado River Cutthroat Trout

The Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) is a state species of special concern. Their decline is due to the same factors that affect greenback cutthroat trout, namely competition and hybridization with non-native fish, pollution, and habitat destruction.

Colorado River cutthroat trout spawn after water flows have peaked in spring or early summer. In Rocky Mountain National Park, Colorado River cutthroat trout occur primarily in the Colorado River, Timber Creek, Onahu Creek, North Inlet, Ptarmigan Creek, and Paradise Creek. Due to extensive restoration efforts by the Colorado Division of Wildlife and U.S. Fish and Wildlife Service, this species has been removed from the state list of threatened species. Any alteration of riparian areas or water quality has the potential to impact the Colorado River cutthroat trout.

Greater Sandhill Crane

The greater sandhill crane is a state species of special concern. The crane population was greatly reduced by the 1940s due to hunting, habitat change, and disturbance. Although generally thought to be very sensitive to human disturbance, some cranes have been found to nest in close

proximity to areas such as highways (Barrett 1998).

Greater sandhill cranes arrive in Colorado by May to breed, have young in June, and migrate in August (Andrew and Richter 1992). There is only one known pair of cranes that nest in the park; they have returned to the Kawuneeche Valley since 1997 to nest in a riparian willow/herbaceous area along a beaver pond. Any alteration of riparian areas or water quality has the potential to impact the greater sandhill crane.

Long-billed Curlew

The long-billed curlew is a state species of special concern. The closest area to the park where it breeds and nests is in eastern Larimer County. It is considered a rare migrant through the park and has been sighted in Moraine Park in the fall and spring on occasion.

The habitat of the long-billed curlew includes riparian areas and shorelines (Andrew and Richter 1992). Elk range overlaps with potential long-billed curlew migratory habitat in the park; therefore, any potential management activities associated with the alternatives may affect the curlew.

Bald Eagle

The bald eagle is a state-listed threatened species. Bald eagles have made a dramatic recovery since the pesticide DDT was banned, and they were [removed from the federal list of threatened and endangered species in August 2007.](#) They require undisturbed habitat with minimal human activity. Recreational activities, such as camping, have been shown to adversely affect the behavior of adult eagles and likely the survival of their young (Steidl and Anthony 2000).

Bald eagles breed in March and have young in April, which completely leave the nest by the end of August (Andrew and Richter 1992). Bald eagle populations in Colorado increase dramatically in the winter, when they move to the plains and western rivers and parks (Winternitz 1998). This same pattern occurs with bald eagles in Rocky Mountain National Park: in the summer one bald eagle pair forages in the park and in the winter up to six pairs do so. The eagles primarily use habitats on the west side of the park between Shadow Mountain Dam and Columbine Bay, which is not within the elk range, although their foraging territories could extend into the elk range. [Bald eagles are not known to nest within the park.](#) Bald eagles primarily feed on fish in reservoirs and rivers. However, they also feed on dead or crippled animals such as waterfowl or winter-killed deer and elk. Therefore, management activities that could affect carrion availability and quality could also affect the bald eagle population.

River Otter

The river otter is a state threatened species that was downlisted from endangered by the Colorado Division of Wildlife in 2003. Otter populations have diminished as a result of habitat alterations, human encroachment, trapping, water diversions, and degradation of water quality. The river otter was formerly extirpated from the park, but 43 otters were reintroduced to the park in the upper Colorado River between 1978 and 1984 (Armstrong 1987). Based on otter population surveys performed in 2001 (Herreman and Ben-David 2001), the otter population along the Colorado River in the park was estimated to be 18 animals.

Fish are usually the otter's primary food item, but they will eat frogs, insects, and aquatic birds when available. The presence of shrubs and stream shading are important variables that contribute to otters' habitat selection in the park (Herreman and Ben-David 2001). River otters in

Rocky Mountain National Park breed in spring, but implantation does not occur until the following spring. Young are born in March or April (Armstrong 1987).

Management activities that could affect riparian vegetation along the Colorado River or actions with potential to affect water quality could affect the river otter.

Wolverine

The wolverine is a state-listed endangered species. Currently, the wolverine is either extirpated from Colorado and the park or there are too few for a viable population (Seidel et al. 1998). Intensive survey efforts throughout Colorado, including 5,833 miles of snow tracking, 62 locations of hair snags, 110 locations of remote infrared cameras, and 686 trap nights of snares found only 10 sets of tracks that appeared to have a high probability of being a wolverine. None of these tracks were in or near the park (Seidel et al. 1998); however, since 1953, 84 probable sightings have been reported in Rocky Mountain National Park.

Although their existence in Rocky Mountain National Park has not been confirmed, wolverines elsewhere breed in summer, but implantation does not occur until January. In Alaska, young are born in March and leave the nursery den in April or May (Armstrong 1987).

The State of Colorado considers the species critically imperiled and has created the *Draft State of Colorado Conservation Strategy for Lynx and Wolverine* (Seidel et al. 1998). Rocky Mountain National Park is a signatory to the plan and may supplement additional wolverines if they are determined to be found in the park. However, this would need to be done in cooperation with Colorado Division of Wildlife (and consequently the Colorado state legislature) because the park is too small to support a wolverine population on its own. There are currently no foreseeable plans by the state or park to reintroduce the wolverine.

Wolverines are very susceptible to human activities and may abandon their den sites in response to such minor disturbances as cross-country skiers (Copeland 1996). Elk range overlaps with wolverine habitat in the park; therefore any potential management activities associated with the alternatives may affect wolverines.

Wolverines are opportunistic carnivores that primarily feed on carrion. They typically occur in very low densities at mid to high elevations (Ruggiero 1994). Currently within the park, wolverine and elk habitat use primarily overlaps in the summer, but since elk mortality is very low in the summer, it is unlikely that elk are a major source of food for wolverines. In winter, any mortality among the 100 to 200 elk that live in alpine areas of the park likely provides food for wolverines. Therefore, there is potential for management activities to impact wolverines by altering carrion availability and quality.

Canada Lynx

The Canada lynx, a federally listed threatened species and state listed endangered species, was reintroduced into southwestern Colorado by the state starting in 1999 with the purpose of establishing a viable population. During that first winter, the division had 19 records of four radio-collared lynx moving north from their release site and spending some time in or near the park between October 8, 1999 and April 28, 2000. Subsequent documented occurrences of lynx in the park include the latest noted on October 30, 2005.

The park contains approximately 145,815 acres (54% of the park) of potential lynx habitat. Mature conifer forests are necessary for denning, and riparian areas are frequented during the summer. Lynx are a specialized carnivore: snowshoe hares (*Lepus americanus*) provide up to

97% of their diet (Koehler and Aubry 1994). Although uncommon, carrion (including ungulates) can also make up a large portion of a lynx's diet when other prey sources are scarce (Brand et al. 1976). Therefore, there is a potential for management activities to impact lynx due to alteration of carrion availability and quality.

Human presence can have a major impact on lynx survival and behavior. For example, roads can be a primary source of mortality for lynx (Halfpenny et al. 1999), and human activities, particularly in the winter, can cause lynx to avoid prime habitats (Oliff et al. 1999). However, repeated and consistent human disturbance will not necessarily preclude lynx from using an area, as they may adapt behaviorally or physiologically (Bowles 1995). Elk range overlaps with potential lynx habitat in the park; therefore, any potential management activities associated with the alternatives may affect lynx.

Species Excluded from Further Analysis

All species presented in Appendix D were considered during the development of this document. The bonytail (*Gila elegans*), Colorado pikeminnow (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), and razorback sucker (*Xyrauchen texanus*) do not occur in the park, but are federal downstream species in the Upper Colorado River basin. The least tern (*Sterna antillarum*), pallid sturgeon (*Scaphirhynchus albus*), piping plover (*Charadrius melodus*), and whooping crane (*Grus americana*) also do not occur in the park, but are federal downstream species in the South Platte River basin. None of these species are expected to be impacted by the alternatives addressed in this plan. Although the plan will likely result in the return of beavers and beaver ponds and therefore a potential Endangered Species Act water depletion concern because of evaporative losses, this will not be considered an Endangered Species Act issue because it will result in the return of natural conditions that likely existed before the elk population expansion; therefore, these species will not be retained for analysis.

The Preble's meadow jumping mouse (*Zapus hudsonius preblei*) does not occur in the park, but occurs at lower elevations in the state. None of the actions associated with the plan are expected to affect the jumping mouse or its habitat. The yellow-billed cuckoo (*Coccyzus americanus*) does not occur in the park except accidentally, but is found at lower elevations in Grand County. Although the Mexican spotted owl (*Strix occidentalis lucida*) does not currently occur in the park, there may be some potential suitable habitat in the park. However, neither the owl's prey base nor habitat overlap with current or possible activities related to this plan. These federally listed species are not expected to be impacted by the alternatives addressed in this plan and will not be retained for further analysis.

Colorado butterfly plant (*Gaura neomexicana* spp. *coloradensis*) is a federally listed threatened species. The biggest threats to the plant are non-selective herbicide spraying, agricultural activities, water development, competition from exotic plants, and loss of habitat to urban growth. The plant grows in riparian areas at elevations below 7000 feet, outside of the evaluated elk range, and management actions associated with this plan would not affect the Colorado butterfly plant; thus it is not retained for further analysis.

Ute ladies'-tresses (*Spiranthes diluvialis*) is a federally threatened species. The major threats to the species are related to loss of habitat from agriculture and development. The plant grows in riparian areas at elevations below 7000 feet, outside the elk range that is being evaluated, and management actions associated with this plan would not affect Ute ladies'-tresses. This species will not be retained for further analysis.

The Barrow's goldeneye (*Bucephala islandica*), ferruginous hawk (*Buteo regalis*), and American white pelican (*Pelecanus erythrorhynchos*), state-listed species of special concern, all migrate

through the park. Because these species do not nest in the park and the habitat which they use while migrating is not expected to be impacted by the alternatives, these species will not be retained for further analysis.

The American peregrine falcon (*Falco peregrinus anatum*), a state-listed species of special concern, has nested in the park cliffs on Sheep Mountain, Lumpy Ridge, and Cow Creek area. Despite not occurring in the park at this time, neither its food source nor its habitat overlap with current or possible activities related to this plan, and will not be retained for analysis.

The Rocky Mountain capshell snail (*Acroloxus coloradensis*), a state-listed species of special concern, occurs only at Finch Lake in the park. This species will not be retained for further analysis because lakes are not expected to be impacted by any alternatives in this plan.

OTHER WILDLIFE SPECIES

Nearly 350 vertebrates are found in the Rocky Mountain National Park area, including 276 species of birds, 52 mammals, 11 fish, four amphibians, and one reptile. The distribution of species within the park varies by season, elevation, and varieties of habitats present. Species that are not threatened or endangered but may be affected by elk management activities are described in this section. Appendix E contains a list of wildlife species found in the park.

Amphibians and Reptiles

Amphibians that occur in the park include the boreal toad (*Bufo boreas*; see “Special Status Species” section), tiger salamander (*Ambystoma tigrinum*), western chorus frog (*Pseudacris triseriata*), and wood frog (*Rana sylvatica*). Amphibians generally prey on invertebrates, though some may eat small vertebrates.

The only known reptile in the park is the western terrestrial garter snake (*Thamnophis elegans*). The garter snake frequents riparian habitat.

Fish

As discussed in the “Special Status Species” section, native fish species that occur in the park are greenback cutthroat trout (*Oncorhynchus clarki stomias*) and Colorado River cutthroat trout (*O. clarki pleuriticusottus bairdi punctulatus*; west slope). Other native fish species include mountain sucker (*Catostomus platyrhynchus*; west slope), western longnose sucker (*C. catostomus griseus*), western white sucker (*C. commersoni suckii*; may be introduced in west slope waters), and mottled sculpin (*Cottus bairdi*).

Exotic fish that occur in the park are brown trout (*Salmo trutta*), eastern brook trout (*Salvelinus fontinalis*), rainbow trout (*Oncorhynchus gairdneri*), and Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*).

Small- to Medium-Sized Mammals

Small- to medium-sized mammals in the park include the deer mouse, montane vole, least chipmunk, Uinta chipmunk, chickaree, Wyoming ground squirrel, golden-mantled ground squirrel, Abert’s squirrel, northern pocket gopher, Nuttall’s cottontail, snowshoe hare, pika, and yellow-bellied marmot. Small mammals in the park are found in a variety of habitats.

Ungulates

In addition to elk, three other ungulates occur in Rocky Mountain National Park: mule deer (*Odocoileus hemionus*), bighorn sheep (*Ovis canadensis*), and moose (*Alces alces*). These ungulates are spatially segregated for part of the year: moose primarily occur on the west side of the park during the summer in the vicinity of the Kawuneeche Valley; mule deer occur throughout the park in the summer, but in winter are most often found on the east side of the park near or overlapping with elk winter range areas; and bighorn sheep are found in several mid- to high-elevation areas throughout the course of the year. Elk, which considerably outnumber the other ungulates in and near the park, overlap with all of these ungulates due to their large seasonal migrations.

Ungulates may compete for forage if the two species in question have overlapping diets, overlap in range use, and one or both have levels of forage consumption large enough to limit available forage (Hobbs et al. 1996a, Hobbs et al. 1996b). If competitive effects are strong enough and favor a particular ungulate at the expense of another, this can affect the production, distribution, and/or population size of another species (e.g., Hobbs et al. 1996a, Hobbs et al. 1996b, Forsyth and Hickling 1997).

Mule Deer

The number of mule deer that inhabited the Rocky Mountain National Park area before 1915 is unknown, but it is clear that mule deer were heavily hunted and suffered large declines throughout Colorado and the Rocky Mountain National Park area during the late 1800s and early 1900s (Stevens 1980a, CDOW 1999). After Rocky Mountain National Park was created, deer populations increased until 1938, apparently at least partially in response to management actions aimed at protecting them from poachers and predators (Monello et al. 2005). Since 1938, deer populations have declined, initially possibly due to an overpopulation of mule deer reducing their own forage base (Stevens 1980a), and from 1943 to 1958 in response to a deer reduction program that was instituted in conjunction with the elk reductions to improve range conditions on the east side of the park. Deer numbers appeared to continue to decline even after reductions were terminated in 1968. This is not unique to the Rocky Mountain National Park area, as the entire western U.S. has observed a decrease in mule deer numbers since at least the 1970s (CDOW 1999).

Mule deer summer throughout the east side of the park and on the west side in areas such as the Kawuneeche Valley, Specimen Mountain, and the North Inlet Drainage. They also summer in the northern portions of the park in the Poudre Drainage and the Long Draw Reservoir areas. During the winter, deer in the North Inlet Drainage move southwest out of the park or move to the east side. Deer in the upper Kawuneeche Valley and Poudre Drainage move south and east toward the Estes Valley. Deer near Long Draw move either northeast to the lower parts of the Poudre Canyon or southeast toward the Estes Valley. The primary mule deer winter range within the park is on the east side below 9500 feet in the montane life zone, overlapping with elk winter range. Connor et al. found that the mule deer population size decreased 11% between 2001 and 2003, from 833 to 561 (2004). They also reported that adult female survival for Estes Valley was about 10% lower than expected for female mule deer in the intermountain west, and concluded that the low survival rate may be at least partially responsible for the population decline. The mule deer population estimates for the past two winters indicate that there are 500 to 600 mule deer in the Estes Valley population (Watry 2005g).

Ecosystem modeling suggests that under natural conditions and with wolves present in Rocky Mountain National Park, deer populations on elk winter range areas would be limited to approximately 200 animals (Coughenour 2002). The same model also predicts that without wolves, deer would be limited to a similar population size through competition with elk.

Competition with Elk

Although mule deer are considered browsers and elk as grazers, elk can have a large impact on mule deer through physical exclusion and competition for food. Kufeld et al. summarized the diet of mule deer in the Rocky Mountains and found it largely composed of browse (shrubs and trees) and forbs throughout the year, with a low to moderate use (~20%) of grasses in the spring (1973). Deer exhibit their greatest need for browse during winter because they cannot subsist on dry, senescent grasses (CDOW 1999, Kufeld et al. 1973). Stevens found that in the park during

winter, mule deer diets consisted largely of browse, including bitterbrush (25%), big sagebrush (15%), green rabbitbrush (13%), and wax current (7%), along with small amounts of various other species; forbs made up 16% and grasses made up 14% of the winter diet (1980). Elk can also greatly increase their intake of browse species when grasses are unavailable or the nutritional quality of grasses becomes less than browse, such as during winter (Hobbs et al. 1981).

Deer are smaller than elk and can be displaced from preferred feeding areas (CDOW 1999). Because elk are competitively dominant, are at carrying capacity on their winter range in Rocky Mountain National Park, which overlaps considerably with mule deer winter range areas, and are having an effect on upland shrub species, they may have negative impacts on mule deer production and population size (Hobbs et al. 1996a, Hobbs et al. 1996b, Forsyth and Hickling 1997, CDOW 1999). This is indirectly supported by the fact that deer numbers and habitat use continued to decline while elk numbers and habitat use increased in the best deer habitats (upland shrub) after the control program was terminated in the park (Zeigenfuss et al. 2002). In general, elk and deer population estimates over the last 50 to 75 years from Rocky Mountain National Park are inversely correlated. Continued mule deer declines throughout the 20th century in conjunction with an increasing elk population suggest that elk may be affecting mule deer. However, it should be noted that in 1949 and 1952, Guse identified declines in the winter and summer populations, respectively, well before the control program was terminated (1966).

Chronic Wasting Disease

Mule deer in Rocky Mountain National Park are infected with chronic wasting disease. Out of 261 mule deer sampled in the Estes Valley and Rocky Mountain National Park east side wintering population between 1997 and 2002, chronic wasting disease was prevalent among 5.4% (Connor et al. 2004). Simulation modeling predicts chronic wasting disease has the potential to cause drastic population reductions in deer (Miller et al. 2000, Gross and Miller 2001). However, this does not mean the population declines in mule deer over the last 50 to 70 years are due to chronic wasting disease; chronic wasting disease was not detected in free ranging cervids until the 1980s and was not documented in mule deer in the park until 2001. Mule deer have declined throughout Colorado and the western United States, including areas where chronic wasting disease have not been documented (CDOW 1999). Currently, Rocky Mountain National Park removes any deer that display clinical signs of chronic wasting disease and any deer that test positive through a live test. All carcasses that are found are removed if possible and also tested.

Bighorn Sheep

Bighorn sheep are particularly sensitive to human disturbances. Prior to 1880, bighorn sheep were reported to be much more abundant and occupy a much greater area in Rocky Mountain National Park than they currently do (Ratcliff 1941, Packard 1939). Ratcliff suggested that there may have been as many as 4000 sheep in the park during the early 1800s (1941). From the time the Estes Valley was settled up to the current time, bighorn numbers have varied in the park. Declines have occurred due to market hunting, competition with livestock, development, and disease (Packard 1939, Packard 1946, Goodson 1978, McClintock 2004), while at other times populations have been stable or increased, partially in response to intensified management (Contor 1958, Capp 1967, Goodson 1978). Most recently McClintock estimated the population size of west side population to be about 290 bighorn sheep, and the size of the mummy range population to be about 80 bighorn sheep (2004).

Competition with Elk

Bighorn sheep are primarily found at higher elevations in the park. Elk use these areas, especially during the summer and fall but also in small numbers during the winter. Capp (1967) and Harrington (1978) examined summer range use by elk and bighorn sheep in alpine areas of Rocky Mountain National Park and found bighorns and elk were spatially segregated: bighorns tended to use steep, rocky slopes while elk used open meadow areas. Capp (1967) and Singer et al. (2002) found elk in alpine areas to primarily consume forb and browse species (willow) in the summer, while bighorns primarily consume grasses (Capp 1968). Based on this evidence, there appears to be little competition for food or range use between elk and bighorn sheep in Rocky Mountain National Park. However, the population size and range use of elk has increased considerably since the study periods of Capp (1967) and Harrington (1978), and elk are capable of displacing sheep from preferred feeding areas (Goodson 1978). Overall, competition between elk and bighorns is likely of little consequence to sheep when compared to such factors as disease.

Disease

Pneumonia-induced die-offs (*Pasteurella* spp.) are the principal factor affecting bighorn sheep population dynamics in the western United States. Bighorn populations on the east side of the park, and possibly those on the west side, experienced a pneumonia-induced die-off in 1994. It appeared that few of the lambs born in the Mummy Range sheep population between 1994 and 2001 survived to become yearlings), with questionable lamb survival in west side populations as well. Many pathogens associated with pneumonia epidemics are present in bighorn ewes of both east and west side populations; of concern are small yearling ratios observed suggesting the population is not recruiting at levels needed for sustainable growth (McClintock 2004).

Moose

Historically, moose (*Alces alces*) were not common in Colorado or Rocky Mountain National Park. There is only one recorded historic occurrence of a moose in the park: Estes (1939) reported killing a moose in Moraine Park in 1860. In 1978-79, the Colorado Division of Wildlife introduced 24 moose to the North Park area, about 19 miles northwest of Rocky Mountain National Park, to establish a viable moose population for hunting. A moose was first observed in the Kawuneeche Valley in 1980, with the first winter observations in 1985. The current population in Rocky Mountain National Park is estimated to be about 100 moose (Dungan 2005). Moose are primarily found west of the Continental Divide in the Colorado River drainage, but occasionally are observed east of the Continental Divide. About one-fourth of the total population occurs in the Kawuneeche Valley.

Moose in Colorado are close to the southern limit of their distribution in the United States. Studies conducted in other areas suggest that bears and wolves may limit the size and density of moose populations and their localized effects on vegetation (Bergerud et al. 1983, Ballard et al. 1987, Boutin 1992, Peterson 1999). The absence of wolves in Rocky Mountain National Park could be resulting in higher densities of moose with greater effects on the plant community than would occur with an intact predator base (Monello et al. 2005).

Competition with Elk

Moose and elk use the Kawuneeche valley in spring, summer, and fall. Late fall and winter use of the valley by moose appears to be minimal, while some elk do use the Kawuneeche Valley during winter (Dungan 2005). The extent of site-specific overlap in moose and elk habitat use in

the park is not known; however, studies in other locations found that moose were not tolerant of large groups of elk and maintain some separation in their distribution (Peek and Lovaas 1968, Jenkins and Wright 1987). Willow make up 93% of summer moose diets in the park (Dungan 2005). Moose and elk use the willow communities in the Kawuneeche Valley during late spring and summer. Although no studies have been conducted to separate elk from moose herbivory impacts, elk occur in larger numbers, are more sedentary in more vulnerable willow patches, and browse in spring, which is a more critical time for willow as they put on growth for the year (Cooper and Westbrook 2005).

Predators and Scavengers

Potential predators of elk in the park and surrounding areas include mountain lion (*Felis concolor*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), black bear (*Ursus americanus*), and golden eagle (*Aquila chrysaetos*). Gray wolf (*Canis lupus*) and grizzly bear (*Ursus arctos*) are other native predators; however, these species no longer occur in the area. Gray wolves were likely gone before the park was established, and the grizzly bear disappeared soon after the park was established (Armstrong 1987). Predator populations in the park were controlled from 1917 to 1926 to encourage recovery of ungulate populations, with records of approximately 50 coyotes and 20 mountain lions eliminated (Stevens 1980a). However, the predator control program probably benefited deer populations more than elk; at the time of control programs, elk populations appeared to continue to increase (Stevens 1980a).

Mountain lion and coyote can kill healthy adult elk, but their primary prey typically consists of bighorn sheep, deer, or small mammals (Hornocker 1970, Gese and Grothe 1995, Smith and Anderson 1996, Crabtree and Sheldon 1999, Kunkel et al. 1999). No studies have suggested that mountain lions or coyotes have the ability to limit elk population size, and the finding that elk in the park have reached their carrying capacity (Coughenour 2002, Lubow et al. 2002, Singer et al. 2002) in the presence of unexploited mountain lion and coyote populations indicates neither predator has a significant effect on elk populations in the area.

It is not known how many mountain lions inhabit the park; however, they are observed fairly frequently. They are most abundant in broken country with good cover of brush or woodland. In the park and surrounding areas, mule deer are their primary prey; however, elk are taken occasionally (Armstrong 1987).

Coyotes are common in the park. They are highly adaptable animals and range through a wide variety of habitats. Coyotes have a broad diet that consists principally of small- to medium-sized mammals and some birds (Armstrong 1987). Larger prey, such as deer or elk, is taken on occasion, especially when snow or ice impedes travel for ungulates. Coyotes have been observed killing young calves and appear to spend more time hunting in prime calving areas when cows are giving birth than other times of the year. During winter, scavenging can be important.

Bobcat are considered common in the park. They occur in woodland, shrubland, and forest-edge habitat throughout the park. The primary prey of bobcats consists of rabbits, hares, and a variety of other small mammals and birds, but they may also take elk calves if circumstances permit (Armstrong 1987, Bear 1989).

Black bear are strongly tied to forested habitats (Rogers 1976, Powell et al. 1997). They are omnivorous, eating plant and animal matter, and primarily scavenge rather than kill elk, but can be effective predators of elk, especially calves (Knight et al. 1999, Smith and Anderson 1996). Research on black bears in the park conducted from 1985 to 1991 found that less than 8% of black bear diets consisted of mammals, and elk were not among the mammal species identified (Zeigenfuss 2001). In general, the park provides poor to marginal black bear habitat, and bear

densities are relatively low, bears are small, and cub survival is low relative to other populations in Colorado (Zeigenfuss 2001, McCutchen 1993). The population size in the park is estimated to be 20 to 25 bears (Zeigenfuss 2001).

Golden eagles are known to breed in the park and are observed fairly frequently. They feed primarily on small mammals. Prey remains of bighorn sheep lambs have been found in nests, and while golden eagles could take elk, especially calves, predation on elk has not been documented in the park.

Scavengers in the park include black bear, coyote, mountain lion, bobcat, red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), common raven (*Corvus corax*), gray jay (*Perisoreus canadensis*), Steller's jay (*Cyanocitta stelleri*), black-billed magpie (*Pica hudsonia*), and turkey vultures. Bald and golden eagles have been observed feeding on elk carcasses.

Other Species Associated with Elk Grazing and Behavior

Birds

Over 300 bird species have been observed in the Rocky Mountain National Park area. Birds in the park include year-round residents, seasonal migrants and breeders, and occasional visitors. The large majority of these birds are seasonal residents; only 26 species are considered common, year-round inhabitants of the park. The Partners in Flight North American Landbird Conservation Plan (Rich et al. 2004) identified bird species of continental importance that need to be managed to reverse long-term declines, and 13 of these (22%) are known to occur in Rocky Mountain National Park. Birds in the park that could be affected by elk include ptarmigan, songbirds/neo-tropical migrants, raptors (also see "Predator" section), waterfowl, and shorebirds.

Ptarmigan

White-tailed ptarmigan (*Lagopus leucurus*) are members of the grouse family that primarily inhabit elevations above treeline. During the winter, they are found only in areas where willow is a dominant or co-dominant plant species. Their diet is dominated by willow buds, leaves, and twigs from October to June, but is more diverse during the summer and includes herbaceous and browse species (May and Braun 1972).

Between 1975 and 1991, the size of the ptarmigan populations that occur on elk summer range along Trail Ridge Road in the park fluctuated, with substantial variation observed between years in average brood sizes and adult survival (Braun et al. 1991, Wang et al. 2002a). Braun et al. found that the decline was concurrent with a decline in willow cover and an increase in elk population size and suggested that heavy use of willow by elk in early winter and early spring constrained ptarmigan breeding densities by reducing the amount of food available to ptarmigan in late winter during the early breeding period when ptarmigan establish breeding territories. They further suggested that expansion of elk population and range in the park might affect ptarmigan population dynamics (1991). However, Wang et al. analyzed 1975 to 1999 data on population growth rates of ptarmigan and elk population sizes and determined that elk population sizes were not related to population growth rates (2002a). Wang et al. found that local weather exerted a stronger influence on the population dynamics of ptarmigan (2002b).

Songbirds

At least 150 songbirds have been observed in the park. About one-third of these are neo-tropical migrants, defined as birds that spend winter south of the United States or Tropic of Cancer (Connor 1993). Many neo-tropical migrants and songbirds breed in the park (Johnsgard 1986). The diversity of songbirds and neo-tropical migrants in the park is greatest in aspen, riparian willow, and ponderosa pine habitat (Connor 1993, Turchi et al. 1994), which combined make up only 9% of the park area. The primary elk winter range in the park is important for songbirds because it contains 55% of these habitat types. The Kawuneeche Valley contains 9% of the park's aspen and willow riparian habitat. These areas are the only large, continuous areas of such habitat.

Turchi et al. found bird species richness to be significantly higher in aspen than conifer habitat, and percent shrub cover (0.5-2 m or 1.5 to 7 feet in height) within aspen stands to be the single most important predictor variable for bird species richness in the park (1994). About 13 avian species breed almost exclusively in aspen, including Williamson's and red-naped sapsuckers, which are species of continental importance (Rich et al. 2004). Cavity-nesting species such as woodpeckers, swallows, bluebirds, chickadees, and nuthatches use live and dead standing trees, including aspen, as roosting and nesting sites. Zaninelli and Leukering (1998) and Duberstein (2001) suggest that live aspen trees are more important to cavity-nesting birds than dead trees, and that different bird species used different sizes and densities of aspen. Lloyd (1997) surveyed bird species present in aspen stands on and off the winter range, and found the mountain chickadee to be more abundant in stands located off the winter range. He attributed this to the fact that mountain chickadees tend to inhabit coniferous forests, which are much more abundant around aspen stands off the winter range versus on.

Riparian habitats support the highest bird diversity of any western habitat type, while being one of the rarest (< 4% of the park). Black swift, dusky flycatcher, red-naped sapsucker, rufous hummingbird, Lewis's woodpecker, and calliope hummingbird occupy various riparian habitats. Bird species specifically associated with willow include Wilson's warbler, Lincoln's sparrow, fox sparrow, song sparrow, yellow warbler, and white-crowned sparrow. Long-term bird monitoring in willow habitat indicates that the fox sparrow disappears from willow habitat when heavy willow grazing impacts the lower half of the shrub and understory vegetation. Leukering and Carter found that different bird species in the park used different sizes and densities of willow, indicating that short and tall willow are both important (1999).

Montane shrub (upland shrub) habitats, composed of antelope bitterbrush, sagebrush, *Ribes* spp., *Potentilla* spp., and common juniper, provide many avian species with valuable food and cover. Montane shrubs may be critical to western hummingbirds during migration. Brewer's sparrow, sage thrasher, dusky flycatcher, Virginia's warbler, calliope hummingbird, green-tailed towhee, rufous hummingbird, and mountain bluebird are species of continental importance (Rich et al. 2004) that use upland shrub habitat in the park. Jelhe et al. found the three most frequently observed species in upland shrub habitats were green-tailed towhee, house wren, and western wood-pewee (in review). Other species commonly observed included American robin, broad-tailed hummingbird, chipping sparrow, mountain bluebird, pine siskin, red crossbill, Steller's jay, violet-green swallow, and yellow-rumped warbler. Green-tailed towhees and sage thrashers nest exclusively in montane shrub habitat type. Partners in Flight (Rich et al. 2004) gives Colorado a high responsibility for conservation of the green-tailed towhee because Colorado contains 20% to 40% of the entire breeding population of this species (Kingery 1998). Jelhe et al. found that three shrub species accounted for more than 90% of green-tailed towhee nest locations: 47% were in common juniper, 38% were in sagebrush, and 9% were in antelope bitterbrush (in review).

Alpine tundra is a specialized, fragile habitat type. Black- and brown-capped rosy finches are two alpine tundra specialists that are species of continental importance (Rich et al. 2004). The brown-capped rosy finch, which breeds only on alpine peaks of the Intermountain West, has one of the smallest populations and ranges of any North American land-bird.

Raptors

Three species of *accipiters* — northern goshawk (*Accipiter gentilis*), Cooper's hawk (*A. cooperii*) and sharp-shinned hawk (*A. striatus*) — breed in the park. Their long tails and short, broad wings enable them to hunt in densely wooded habitat. Nests have been found in lodgepole pine and aspen, in or near small groves of aspen, and in riparian areas intermixed with dense lodgepole pine and Douglas fir within 550 yards of open meadows. A high proportion of accipiter nests in the park have been found in the elk winter range in the montane zone. Their nests tend to be on north-to-northwest-facing slopes but have also been found on east facing slopes. The northern goshawk often hunts in open meadows where their principle prey, the Wyoming ground squirrel (*Spermophilus elegans*), is abundant. Other prey used by the three species of accipiters includes birds, chipmunks, chickaree, snakes, and small mammals.

Prairie falcons (*Falco mexicanus*), peregrine falcons (*F. peregrinus*), American kestrels (*F. sparverius*), red-tailed hawks (*Buteo jamaicensis*), and turkey vultures (*Cathartes aura*), can also be found breeding within the park. Prairie and peregrine falcons nest on south facing cliffs below 10,000 feet in the Lumpy Ridge area of the park, and American kestrels nest in tree cavities in ponderosa pine snags. Two prairie falcon pairs breed on south-facing cliffs in the alpine tundra, with one site at 12,000 feet. Their principal prey tends to be birds and to a lesser degree small mammals. American kestrels will also catch large insects such as grasshoppers and butterflies. Red-tailed hawks are the most common raptor in the park and usually nests in old-growth, live ponderosa pines, with some breeding pairs nesting on south-facing cliffs. All known red-tailed hawk nests are within the montane zone in association with ponderosa pine, aspen, and Douglas fir. Turkey vultures, next in size to the two eagles, are scavengers and have been observed feeding on the carcasses of elk, deer, and bighorn sheep. They roost and nest on cliffs, but nests could also be found in hollow logs. They do not build nests, but use scrapes in gravel, or needles and leaves in a log. One colonial roost is known in the Lumpy Ridge area.

The “Special Status Species” section (above) discusses bald eagles and the “Predators and Scavengers” section (above) discusses golden eagles.

Waterfowl

Four species of waterfowl — the mallard, green-winged teal, ring-necked duck and Canada goose — frequently nest in the park. Primary nesting habitat includes the shoreline of beaver ponds, small ponds, and lakes. They occasionally nest along the banks of rivers and streams. Nests are located in dense sedges that grow 1.5 to 3 feet in height along shorelines or may also be found in understory vegetation beneath willow. Young-of-the-year ducklings and goslings rely on dense aquatic vegetation along the edges of ponds and lakes that provide feeding habitat and protective cover from predators. Other species of waterfowl are migrants moving through the park during the spring and fall. The common merganser, Canada goose, common goldeneye, mallard, and rarely the hooded merganser, red merganser, and Barrow's goldeneye can be found during the winter months feeding and roosting in open water along flowing streams.

Only two species of shorebirds, spotted sandpiper and killdeer, are known to nest in the park. Spotted sandpipers nest in a depression in dense grass, sedges, or gravel near the shoreline of beaver ponds, lakes, and streams. Killdeers nest in open, sparsely vegetated, upland habitat in

meadows. Other species of shorebirds that frequent the park are migrants passing through the park in the spring and fall and can be found in association with riparian habitat, wetland meadows, and exposed mudflats in beaver ponds or other small ponds. Long-billed curlews, a rare migrant to the park, have been observed feeding in muddy, water-filled elk wallows in open meadows such as Moraine Park and Horseshoe Park in the fall.

Butterflies

Simonson et al. examined butterfly diversity in six different habitat types on the elk winter range in Rocky Mountain National Park (2001). They found that butterfly diversity, richness, and uniqueness were highest in aspen and wet meadow habitat types and that butterfly species richness exhibited a strong correlation to plant species richness. Plant species most commonly used include sulphurflower, various willow species, and a variety of grass species. A variety of butterfly species in the park have been documented to use these habitat types and species (Bray 2004).

Aspen habitat in the park supports western tiger swallowtail, Weidemeyer's admiral, and the dreamy duskywing, which are considered rare by the state of Colorado.

Sulphurflower, which had 50% less cover in grazed sites than ungrazed sites (Singer et al. 2002) is an important host plant for Sheridan's hairstreak, blue copper, Rocky Mountain blue, and bramble hairstreak (Bray 2004). Willow leaves provide food for caterpillars of Scudder's sulphur, arctic fritillary, frigga fritillary, and the mourning cloak. In addition, four butterflies that spend winter in the park — hoary coma, green coma, Milbert's tortoiseshell, and mourning cloak — depend on the sporadic spring bloom of willows for nectar. Twenty-seven butterfly species in the park use grass and sedge as host plants. Plant leaf litter is important to caterpillars because when they are disturbed while eating leaves, caterpillars often drop to the ground to seek safety. Zeigenfuss et al. found less leaf litter in grazed areas, so in those locations, caterpillars may find it harder to find refuge from predators (1999).

Beaver

Beaver are a keystone species that have profound effects on ecosystem structure and function (Naiman et al. 1988) and have been identified as a focal species for the NPS Inventory and Monitoring Vital Signs Program. Beaver modify their environment by cutting aspen and willow for food and construction material, by building dams that raise the water table, and by building ponds that trap sediment and increase nitrogen availability to willow (Naiman et al. 1988, Baker and Hill 2003). Beaver dams slow current velocity, increase deposition and retention of sediment and organic matter in their ponds, and reduce downstream turbidity on floodplains, increase the area of soil-water interface, elevate the water table, change the annual stream discharge rate by retaining precipitation runoff during high flows and slowly releasing it during low flows, alter stream gradients by creating a stair-step profile, and increase resistance to disturbance (Naiman et al. 1988). Beaver foraging can alter species composition, density, growth form, and distribution of woody vegetation.

Willows provide an important source of food and construction material for beaver. Willow leaves are high in protein content and are readily eaten during the summer. The bark of willow stems may be the only source of winter food for beaver that live in locations where surface water freezes during winter (Baker and Cade 1995). Beaver are central place foragers that cut and remove entire stems at or near the ground surface. They often cut all stems from preferred shrubs growing near their winter food caches, dams, and lodges, but become more selective as foraging distances increase (Baker and Hill 2003).

Beaver cut stems near the ground surface, which stimulates sprouting from the root crown. Increased stem turnover rate and beaver preferences for tall stems increases plant productivity. Factors other than beaver also affect willow growth, such as ungulate browsing, soil type, length of growing season, nutrient concentrations, and water table height (Singer et al. 1994, Cottrell 1995, Peinetti 2000). The interaction of beaver cutting and elk browsing strongly suppresses compensatory growth in willow, which alters the structure and function of the willow community and facilitates conversion from a tall to a short willow community (B. Baker et al. 2005). Beaver in the park prefer relatively tall, unbrowsed willow and select against short, hedged willow (Baker et al. 2004). Thus, willow communities in the park that have been hedged short by elk are largely unsuitable as beaver habitat.

Beaver populations in the park have declined dramatically since 1940. Trapping from 1941 to 1949 probably initiated declines, but intense elk browsing apparently has prevented their recovery (Baker et al. 2004). Elk use of willow leaders averaged 85% during 1968 to 1992 (Zeigenfuss et al. 1999). Beaver populations declined in Moraine Park from more than 300 in 1940 (Packard 1947) to 12 in 1994 to 1998 (Zeigenfuss et al. 2002). Beaver surveys and aerial photographs in 1999 revealed only one beaver colony in Moraine Park. The beaver population on the east slope of the park occurs mostly in areas with low elk use and was about 40 individuals in 1999 to 2001; beaver are largely absent from willow areas with heavy elk use (Baker et al. 2004). Similarly, in the Kawuneeche Valley on the west side of the park, beaver numbers were estimated to be about 60 in 1949 and only 30 in 1999 (Mitchell et al. 1999).

The greater-than-90% decline in beaver numbers in Moraine Park correlates with a 69% reduction in surface water and concurrent willow declines over the last 50 to 60 years (Peinetti et al. 2000, Zeigenfuss et al. 2002). Similarly, a 90% decline in the beaver population in Horseshoe Park contributed to a 47% decrease in surface water and concurrent willow declines (Zeigenfuss et al. 2002). Beaver dams and ponds on the Colorado River in the Kawuneeche Valley [greatly enhanced the depth, extent, and duration of inundation associated with floods \(Westbrook et al. 2006\)](#). Beaver dams raised the water table [during periods of high and low flows](#) and spread water laterally and downstream to locations out of reach of spring floods or other hydrologic processes (Westbrook 2005, [Westbrook et al. 2006](#)). [Each beaver dam studied eased the water table decline that occurs in drier summer months over nearly one quarter of the 58 hectare study area \(Westbrook et al. 2006\)](#).

The lack of beaver accelerates willow declines in Moraine Park and Horseshoe Park by inhibiting the development of appropriate sites for willow seedling establishment and by limiting recharge of shallow aquifers. Abandoned beaver ponds and abandoned channels (ox-bows) associated with beaver are two of the three landform types in the park that provide suitable sites for willow establishment by seed (Cooper et al. 2003). Sediment deposited by beaver dams in the Kawuneeche Valley greatly increased habitat heterogeneity by creating a mosaic of highly variable vegetation establishment and survival patches (Westbrook 2005). Beaver cuttings allow willows to colonize areas that are suitable for willow growth but not for seedling establishment (Cottrell 1995); reproduction via stem fragments is lacking on elk winter ranges that lack beaver. Once established, willows can survive and remain productive for 100 years or longer. Thus, beaver and willows can persist indefinitely as mutualists in a landscape that lacks intense browsing pressure by additional herbivores such as elk.

WATER RESOURCES

Hydrology

Rocky Mountain National Park contains 1143 acres of lakes and ponds, with 167 lakes greater than an acre and 397 less than an acre. Streams in the park total 532 miles, with an additional 38 miles of intermittent streams. The Continental Divide bisects the park into two distinct watersheds; water flowing west drains into the Colorado River, and water flowing east empties into the Missouri and Mississippi Rivers. The headwaters of four major river basins originate in the park, including the Big Thompson, North Fork of the St. Vrain, North Fork of the Colorado, and the Cache la Poudre Rivers. Only the Big Thompson and the North Fork of the Colorado are in the project area. In addition, Fall River, Boulder Creek, and Mills Creek are included for discussion. See Figure 3.6 for a map of the park's streams, rivers, and lakes.

The Big Thompson River flows east through Moraine Park through a series of channels that converge at the far eastern side of Moraine Park. The Big Thompson River, like other rivers and streams in the park, has a flow regime dominated by snowmelt, with approximately 37% of the annual stream flow occurring during June. The low levels of beaver activity in the area has resulted in the stream stage being near stream level most of the summer, which in turn results in limited groundwater recharge and low groundwater levels (Gage and Cooper 2003).

The groundwater of Moraine Park also flows east, where it creates upwelling on the western and southwestern side of a large bedrock outcrop in the center of the park before it continues to flow around the outcrop to the south or dumps into the Big Thompson River on the north. Unlike the shallow and stable groundwater levels at the discharge areas, the groundwater level is much deeper east of the outcrop, creating a large dry area in Moraine Park (Cooper et al. 2003).

Mills Creek flows east through Hollowell Park along two major channels. It is dammed by beavers several times throughout its course. Beaver Brook flows east through Beaver Meadows along one main channel.

Fall River flows east through Horseshoe Park along a strongly meandering channel with pool-riffle morphology (Gage and Cooper 2003). The relationships between stream flow and stage, and groundwater recharge and level, as well as their relationship to beaver activity, are the same as for the Big Thompson River (Cooper et al. 2003).

The Colorado River flows south through the Kawuneeche Valley, and ranges between 25 and 50 feet wide. Between 1954 and 2001, the mean annual discharge was $1.8 \text{ m}^3/\text{second}$, and mean annual peak flow was $16.1 \text{ m}^3/\text{second}$. The flow regime is dominated by snowmelt with marked daily fluctuations in flow during the melt period.

The lowest peak discharge on record was during 2002 at $5.2 \text{ m}^3/\text{second}$ (Westbrook 2005).

The Grand Ditch water diversion has greatly affected the Colorado River. This water diversion project located alongside the Never Summer Mountains predates the establishment of Rocky Mountain National Park. Construction was begun in 1890 and completed in 1936. The 17-mile system delivers an average of 20,000 acre-feet of water annually over the Continental Divide at La Poudre Pass to the eastern plains of Colorado by diverting water from the Colorado River to the Cache la Poudre River. Between mid-May and mid-September of each year, the ditch captures the flow of eleven headwater tributaries of the Colorado River, intercepting an average of 29% of the total annual runoff from the Upper Colorado River Watershed. This reduces instantaneous annual peak flows of all recurrence by as much as 55%, the frequency of overbank

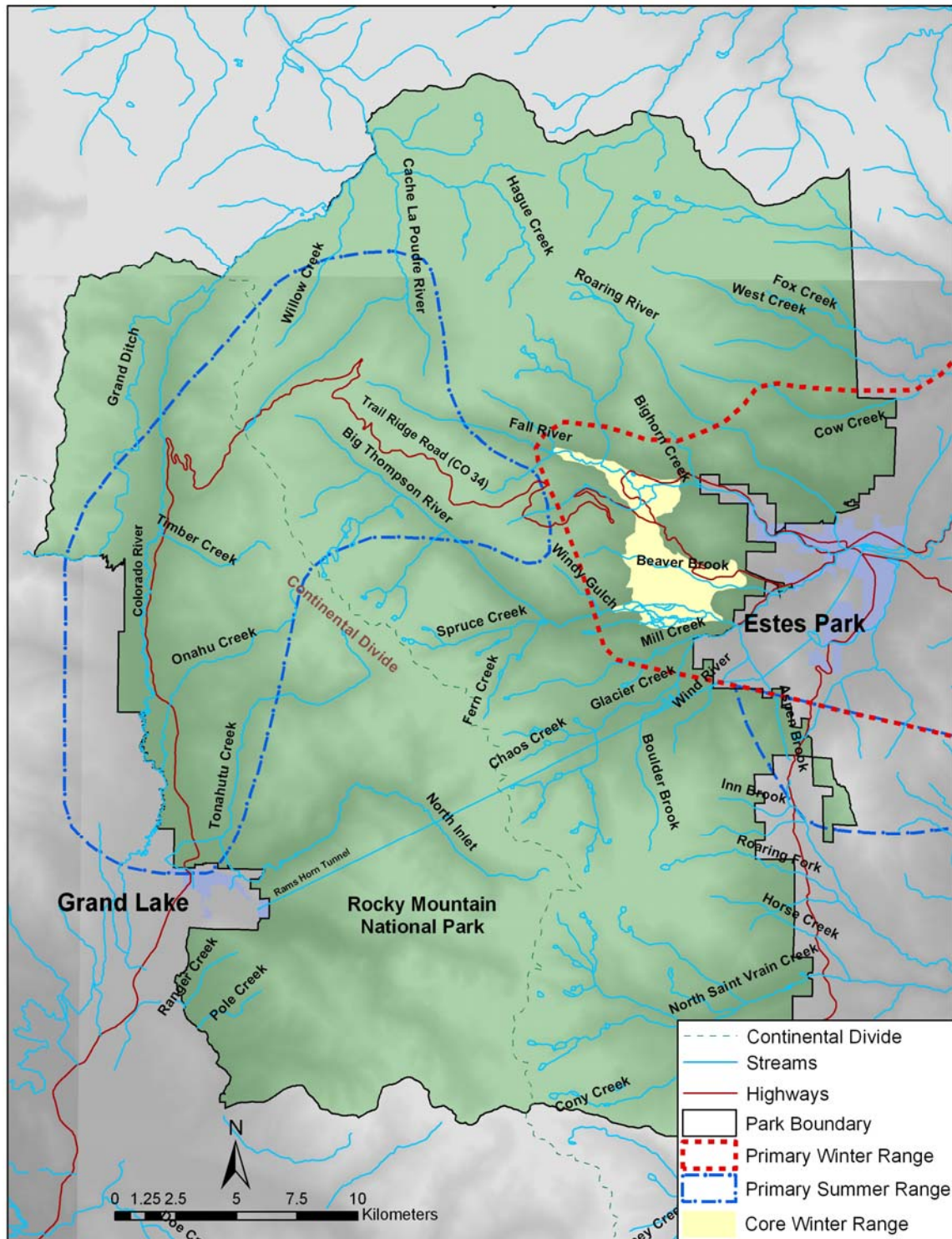


FIGURE 3.6: SURFACE WATERS OF THE PRIMARY ELK RANGE IN ROCKY MOUNTAIN NATIONAL PARK

flooding and channel maintenance flows by about 50%, the amount of surface water in the Colorado River watershed above Baker Gulch by about 50%, and the three-, seven- and 30-day low flows by about 40%. In addition, water levels in the toeslope wetlands of Lost Creek have been reduced by as much as 20 inches, and in Red Creek, more than 20 inches below the surface in a year with low summer rainfall. The impact of the Grand Ditch on river stage and groundwater levels in the Kawuneeche Valley is less noticeable, with approximately a 4- to 8-inch decrease due to the river's large width compared to its depth (Woods 2000).

Effects of Previous Lands Uses and Beaver on Current Hydrology

Previous land uses have played a role in the current hydrology of the park. Rocky Mountain National Park was established in 1915, but additional parcels in Moraine Park and Horseshoe Park were not acquired until 1962 and 1932, respectively. In Moraine Park, development that has affected hydrology includes the Moraine Park golf course, and drainage and irrigation ditches (Peinetti et al. 2001). Within the project area, the Lawn Lake backcountry dam at one time affected hydrology but has since been removed.

Beaver have historically had a significant effect on the hydrology in the project area. Their activities include creating dams and canals, which increase river complexity by slowing water current velocity, elevating the groundwater level, equalizing the water discharge rate by retaining runoff during high flows and slowly releasing it, altering waterway gradients by creating a stair-step profile, and increasing resistance to disturbance within the waterway (Gurnell 1998, Naiman et al. 1988, B. Baker et al. 2005). Beaver, prevalent during the late 1800s and early 1900s, have been declining in the park since 1940, which has altered park hydrology (B. Baker et al. 2005). For more detail on the history and biology of beaver, see the "Other Wildlife" section in this chapter.

Aerial photographs of Moraine Park between 1946 and 1996 show a 56% reduction in length from fewer river meanders and a 69% reduction in the amount of surface area of water from decreased impounding, mostly from beaver ponds of the Big Thompson River. These reductions were attributed to the reduction in beaver activity throughout that same time period (Peinetti 2000). Aerial photographs of Horseshoe Park between 1937 and 1996 show a 44% reduction in length and a 47% reduction in the amount of surface water of the Fall River, which, as with the Big Thompson River, is attributed to the reduction in beaver (Peinetti 2000).

A flood caused in 1982 by the collapse of an earthen dam at Lawn Lake deposited over 750,000 tons of rock at the confluence of Roaring River and Fall River (Jarrett and Costa 1993), creating an alluvial fan at the confluence. The alluvial fan created a new lake called Fan Lake directly upstream that existed from 1982 to 1995, flooding 12 acres of willow habitat.

Downstream, the flood was dispersed into meadow areas and was too small to significantly alter the hydrology of Fall River and the Horseshoe Park area (Jarrett and Costa 1993). However, the debris killed several families of beaver, and more beaver were forced to leave when Fan Lake flooded the willow.

Groundwater depths in the Kawuneeche Valley respond to changes in river stage (particularly in mid to late summer), hillslope runoff, summer rainfall, and recharge from beaver ponds. However, the beaver control over groundwater levels outweighs all other factors, since the beaver dams recharge groundwater in locations far from the river channel and beaver pond (Westbrook 2005, [Westbrook et al. 2006](#)).

With current hydrological conditions, during the growing season water tables near streams of the elk winter range generally remain above approximately three feet (Zeigenfuss et al. 2002, Cooper et al. 2003).

Water Quality

The Water Resources Division of the National Park Service has compiled a baseline water quality inventory for Rocky Mountain National Park (NPS 2001b). The inventory contains surface water quality data from six of the U.S. Environmental Protection Agency's databases for 684 monitoring stations (most were a one-time sampling effort) from 1901 to 1998. The project area includes one mile upstream and three miles downstream of any surface water in Rocky Mountain National Park to completely capture any effects on water quality that might be occurring in the park.

Fifteen groups of parameters exceeded screening criteria at least once within the project area, including dissolved oxygen, pH, chlorine, cadmium, copper, silver, zinc, fluoride, sulfate, nitrite, cadmium, lead, fecal indicator bacteria concentrations, turbidity, and alkalinity (NPS 2001b).

Results are described below:

Approximately 300 observations of dissolved oxygen concentrations below the 4 mg/L level for the protection of freshwater aquatic life occur during depth sampling in Lake Granby.

Of almost 10,000 pH measurements, 2,588 observations were less than or equal to 6.5, while 47 were greater than or equal to 7.0. Data collected in the Loch Vale Watershed (near Bear Lake) accounted for most of these low pH levels, including measurements as low as 1.3 at Sky Pond in 1991. These measurements point to effects of acid deposition.

Turbidity exceeded screening criterion only below Estes Park, outside the park.

Fecal coliform concentrations exceeded the Water Resource Department criterion for 64 data points, some inside the park (near the NPS housing area sewage treatment plant outfall and the National Park Village sewage treatment plant outfall) and outside the park.

Nitrite concentrations exceed drinking water criterion two times (out of 2,798 measurements) in Sky Pond (>1 mg/L) in the park. This is likely due to nitrogen deposition from air pollution.

Sulfate concentrations exceed secondary drinking water criterion from 1941 to 1957 in the Colorado River downstream from Shadow Mountain Lake. No samples since have exceeded this criterion.

Total alkalinity at 160 stations (95% of measurements occurred in the park) were below the NPS Air Resources Division's threshold, indicating sensitivity to acid deposition from 1981 to 1995. No samples since 1995 were included in the Environmental Protection Agency's database.

The data from this study indicated that surface waters within the project area were generally of good quality, with some impact from natural and human activities. Potential natural sources of contaminants include erosion from seasonal flooding and geologic weathering. Potential anthropogenic sources of contaminants include municipal and industrial wastewater discharges (downstream of park), atmospheric deposition, stormwater runoff, agricultural activities (downstream of park), and recreational use (NPS 2001b). Because Rocky Mountain National Park straddles the Continental Divide, it contains only headwaters, with no pollution potential from sources occurring upstream.

Elk and Beaver Effects on Water Quality

The overpopulation of elk is another potential source of water contamination, although no studies have quantified the levels. With more elk than anticipated under natural conditions, it is possible that more fecal coliform and nitrogen from feces and urine are entering surface waters.

In addition, although no quantified observations have been made, there likely has been an increase in turbidity of water due to the reduction in willow along banks, which leads to destabilized banks and increased erosion. A balance of erosion and deposition is expected under natural conditions; however, there may be more erosion than deposition, increasing turbidity of park waters flowing out of the elk range (Cooper 2003).

Although no research has been completed on the subject in the park, the decrease in beaver numbers and their activity since 1940 may contribute to increased turbidity. Beaver dams and canals slow water current velocity and increase deposition and retention of sediment and organic matter in the pond, which decreases turbidity downstream of the dam, increases the soil to water interface, and increases resistance to disturbance (Gurnell 1998, Naiman et al. 1988).

SOILS AND NUTRIENT CYCLING

Background

Soils are largely the result of the geology and geologic processes. Mountains in Rocky Mountain National Park were formed by a series of granitic batholiths intruded into Precambrian mica schists and pegmatites. Glacial activity, occurring as recently as 12,000 years ago, has created much of the geologic landforms evident in the park today by decomposing the mountains. Glacier-carved valleys and their associated features are present along the St. Vrain River, Big Thompson River, Colorado River, and associated tributaries. For example, Moraine Park is the remnant of a glacial lake formed by the Thompson Glacier, and the fine sediments deposited in the lake now support wetland and grassland meadows. Moraines result from the scouring action of glaciers and are composed of unconsolidated rock and debris such as boulders, cobbles, gravel, sand, and clay. Ultimately, the weathering of the glacial and alluvial granites, schist, and gneiss parent material developed soils in the park (Natural Resources Conservation Service [NRCS] 2000).

In 1998, an Order 2 soil survey was completed in the lower elevations of the park and an Order 3 soil survey was completed for other areas of the park. The following general soil properties of the park were reported (NRCS 2000):

Soils of the low elevation valleys are generally very deep, loamy, and formed in alluvium from the nearby mountains. Particularly on the east side of the park, soils have dark-colored surface horizons. In the floodplains, they are poorly or very poorly drained with stratified textures. On stream terraces they are well drained.

Soils of the glacial moraines are very deep, well or somewhat excessively drained, and loamy or sandy with a high content of rock fragments. They formed in till derived mainly from granite, gneiss, and schist.

Soils of the subalpine mountain slopes are generally well or somewhat excessively drained, loamy with a high content of rock fragments, and have light-colored surface horizons. Depth to the underlying bedrock ranges from shallow to very deep. Typically, soil reaction becomes more acid with increasing elevation, as the climate becomes cooler and moister. These soils formed mainly in material weathered from granite, gneiss, and schist.

Soils of the alpine mountains and ridges are generally well drained, loamy with a high content of rock fragments, strongly acid, and have dark-colored surface horizons. These soils formed mainly in material weathered from granite, gneiss, and schist. Poorly drained soils are common in landscape depressions and drainageways.

Compaction, Bare Ground, and Erosion

Elk hoof action is a main factor in soil compaction in the park. Compaction decreases the amount of oxygen in the soil, which eventually can lead to plant death and increased bare ground and soil erosion. In comparing elk exclosure sites and grazed sites after 35 years, research indicates an increase in bulk density in grazed sites (a measurement of soil compaction) for mesic meadow, aspen, and willow vegetation types (Binkley et al. 2003). However, there was no trend identified for the rocky upland sagebrush community. In the grazed sites, increases in bare ground have been observed but do not exceed 5% of the affected area. Increased soil heating, evaporative

losses, nitrogen losses, and erosion may be occurring in these locations (Singer and Schoenecker 2003).

Singer et al. also found that elk grazing has increased the percent of bare ground by 4.6% and increased bulk density of soils by 1.7% on the primary winter range (riparian willow and upland shrub/grassland sites) for sites that had not been protected from elk grazing for four years in Rocky Mountain National Park, although the difference was not statistically significant (2002). Therefore, the transport of soil to waterways is not a concern on most of Rocky Mountain National Park's winter range since the area consists of mostly flat sites and very gentle slopes (Singer et al. 2002).

Zeigenfuss et al. measured a 4% increase in bare ground in transects that were established in 1968 (when elk numbers were released from artificial controls) and measured through 1992 (1999). The only transects with a statistically significant increase in bare ground were in grasslands. Other vegetative communities measured were meadow, willow, aspen, sagebrush, and bitterbrush.

Although not quantified, direct observations in Moraine Park in Rocky Mountain National Park show increased bank instability and erosion due to the reduced amount of willows and their root systems along streambanks.

Nutrient Cycling

Nutrient cycles are considered the cornerstone of ecosystem sustainability, which can be defined as the maintenance of plant communities and nutrient cycles of a particular ecosystem over at least a 50 to 200 year time frame. Ecosystem scientists measure nutrient cycles by determining the amount of nutrient for each stage of a nutrient cycle and by measuring the nutrient content of each material in which the nutrient is stored. This can include measuring nutrients in belowground and aboveground stocks (materials that store nutrients) such as soil, root mass, litter, and aboveground vegetative matter.

Understanding nutrient cycles can be important because depletion of nitrogen and soil organic matter can reduce long-term plant productivity (Vitousek 1982) and could result in change in plant community composition (Schoenecker et al. 2001).

Nitrogen

Nitrogen is one of the most important nutrients for plants; however, it must be fixed into a usable form before plants can use it. Inorganic nitrogen in the atmosphere can only be used by lower-level plants and fungi. The nitrogen cycle involves fixing nitrogen from the atmosphere via bacteria, fungi, and actinomyces, or by lightning. Once nitrogen is available in an organic form, plants can use it to manufacture proteins. Plants can store organic nitrogen, returning it to the biogeochemical cycle when they die. This nitrogen is converted by decomposers to inorganic nitrogen in the form of ammonia, which is then converted to ammonium in a process called mineralization. Ammonium is then converted, via nitrification, into nitrites and, ultimately, nitrates, the very soluble, organic form that plants can use. Nitrogen can also be returned to the atmosphere in a chemical process referred to as denitrification (Pidwirny 2006).

Ungulates, such as elk, can accelerate, decelerate, or have no impact on nutrient cycling. Ungulates consume aboveground nitrogen through herbivory on plants and thereby reduce the amount of plant litter that falls to the soil surface every year. Root biomass and inputs from root turnover are usually thought to be reduced by ungulates. However, in Rocky Mountain National Park root biomass has been shown to increase as a result of elk grazing. Ungulates deposit feces

and urine on the soil surface. Ungulates may also move nitrogen around the landscape on multiple temporal and spatial scales (such as from the winter to summer range). Ungulates and their grazing can alter any of the main components of the nitrogen cycle: nitrogen pools, nitrogen fluxes on an annual basis in and out of their primary winter and summer ranges (e.g., nitrogen loss via erosion, nitrate leaching, ammonia volatilization from ungulate urine), or nitrogen fluxes on a daily basis to habitats within a summer or winter range (Singer and Schoenecker 2003, Schoenecker et al. 2004).

Nutrient acceleration occurs when plant species compensate for herbivory by increasing their growth rates and nutrient uptake.

In Rocky Mountain National Park, research suggests that elk may either not be accelerating nutrient cycling (Coughenour 2002, Schoenecker et al. 2004) or that they may slightly accelerate or decelerate local soil and plant nitrogen concentrations (Binkley et al. 2003, Menezes et al. 2001, Zeigenfuss et al. 2002), depending in part on vegetation communities. Schoenecker et al. (2004) found that ungulate herbivory significantly affected nitrogen mineralization and nitrates in short willow and aspen vegetation communities, and further suggested that nitrogen in being depleted from the willow and possibly aspen vegetation communities. Binkley et al. (2003) measured total soil nitrogen and total soil carbon in the same areas and did not find differences in these nutrient measures. Binkley et al. (2003) and Schoenecker et al. (2004) found almost no net change in nitrogen in upland grass/shrub communities' soils. Because the ecosystems in Rocky Mountain National Park are nitrogen limited, understanding the role of elk in nitrogen cycling is important for future ecosystem sustainability (Menezes et al. 2001).

Some evidence shows that elk may be reducing total nitrogen pools in aspen and short willow communities by transferring nitrogen away from these aspen and willow communities (Schoenecker et al. 2004).

Elk transfer organic nitrogen by spending a large portion of their time feeding while in aspen and willow communities and then spending a large portion of their time resting, defecating, and urinating while in forest and upland shrub communities (Schoenecker et al. 2004). This transfer is important, since nitrogen deposited in urine and feces is 20% to 29% of total nitrogen mineralization (Lane and Montagne 1996). However, Schoenecker et al. detected no decrease in nitrogen mineralization rates in aspen communities (2004).

Schoenecker et al. also suggested that there may be a seasonal net movement of nitrogen from the elk summer to winter range, based on analyzing body mass lost on the winter range (2004).

Other Nutrients

In addition to nitrogen, comparing grazed to ungrazed sites after 35 years showed a substantial decrease in the amount of extractable calcium, magnesium, potassium, and phosphorus in upland shrub communities: 33% on average (Binkley et al. 2003). This was not found in other plant communities studied (aspen and mesic meadow).

Elk, Beaver, and Nutrient Cycling in Rocky Mountain National Park

Elk may also indirectly affect nutrient availability in Rocky Mountain National Park by playing a role in the reduction of beaver populations in the park. Elk herbivory on willows in the winter may affect regrowth of willows, the beaver's winter food. By limiting the beaver's food, elk may be limiting the extent of beavers in the park, thereby affecting nutrient cycling (B. Baker et al. 2005). By flooding areas, beaver cause increases in microbial action in soils (Songster-Alpin and Klotz 1995). In addition, flooding spreads nutrients across the riparian areas (Westbrook 2005).

Beaver increase organic matter in an area threefold, through the damming of sediments and organic materials (Naiman et al. 1988). However, when flooding caused by beaver is reduced and the soils become drier, the nutrients can become firmly bound in the roots of grasses (Ives 1942), making them unavailable to willows.

Microbial Activity

Mycorrhizal fungi have a symbiotic relationship with plants by forming mycorrhizae between plant roots and fungi. These mycorrhizae allow movement of nutrients between plants and fungi, providing benefit to the plants. Carbon flows to the fungus, while inorganic nutrients move to the plant (Sylvia 2004). In nutrient-limited soils, nutrients taken up by the mycorrhizae can lead to improved plant growth and reproduction, so plants with mycorrhizae can more often tolerate environmental stresses than nonmycorrhizal plants.

Herbivores generally affect mycorrhizal fungi negatively, across plant and herbivore species, as their herbivory on plants reduce plants' carbon stock, and, therefore, the amount of carbon transferred to the mycorrhizae (Gehring and Whitham 2002). Herbivory can also affect species composition of mycorrhizal communities (Gehring and Whitham 2002). When moose herbivory on willow species was studied against exclosures, mycorrhizal infections of willow protected from herbivory were increased by up to 42% in the 10-to-15 cm soil depth (Rossow et al. 1997). Therefore, by protecting plants from herbivory, plants are both strengthened by increased mycorrhizae and by reduced aboveground herbivory. There is no data with regards to this in Rocky Mountain National Park.

NATURAL SOUNDSCAPE

The natural soundscape include natural and human components. It also includes the “natural quiet” that occurs in the absence of natural and human sound sources.

The natural soundscape can be defined as the natural ambient sound level of a park. “It is comprised of the natural sound conditions in a park which exist in the absence of any human-produced noises. These conditions are actually composed of many natural sounds, near and far, which often are heard as a composite, not individually” (NPS 2000). In other words, the natural ambient sound level is the total existing sound environment, less all human-caused sound.

Management Policies, Section 4.9 states “Natural soundscapes exist in the absence of human-caused sound. The natural soundscape is the aggregate of all the natural sounds that occur in parks, together with the physical capacity for transmitting natural sounds. Natural sounds occur within and beyond the range of sounds that humans can perceive, and can be transmitted through air, water, or solid materials” (NPS 2006b).

Noise, an element that can degrade the natural soundscape is defined as “...unwanted or undesired sound, often unpleasant in quality, intensity or repetition. . . . In a national park setting, noise is a subset of human-made noises” (NPS 2000). Noise may vary in character from day to night and from season to season. Noise intrusions also have two dimensions: duration and the decibel level relative to the natural soundscape (Harris, Miller, Miller, and Hanson, Inc. 2001).

Noise is generally defined as unwanted or intrusive sound. Sound can be perceived as noise because of loudness, pitch, duration, occurrence at unwanted times or from an unwanted source, or because it interrupts or interferes with a desired activity. A sound that is considered neutral or desirable by one person may be considered unpleasant noise by another person because of a perception of inappropriateness or disturbance, or unwanted content or meaning. Noise can adversely affect park resources or values, including but not limited to natural soundscape, wildlife, and visitor experience. It can directly impact them by modifying or intruding upon the natural soundscape, masking the natural sounds that are an intrinsic part of the environment.

Some human-caused sound is considered acceptable when associated with purposes and uses for which the park was created. Director’s Order 47 (NPS 2000) and *Management Policies* Section 4.9 (NPS 2006b) require park units to determine the level of human-caused sound that is necessary for park purposes and to achieve that level by reducing noise and restoring the natural soundscape to the greatest possible extent.

Soundscape at Rocky Mountain National Park

No park-specific sound measurements were made to determine natural ambient sound levels in Rocky Mountain National Park for this plan. The natural soundscape there includes sounds produced by such sources as wind, thunder, insects, bird and animal calls, falling rocks, streams, and waterfalls. One unique element of the park’s natural soundscape is the bugling of bull elk that can be heard throughout the park during late summer and fall.

Between 30 and 70 commercial flights flying between 15,400 and 19,000 feet pass over the park daily (NPS 2004f). A Federal Aviation Administration Special Flight Rule (FAA SFAR No. 78) temporarily banned the use of low-flying, commercial air tours over Rocky Mountain National Park in 1997 (FAA 2005). Commercial air tour operations over Rocky Mountain National Park were permanently banned by the Federal Aviation Administration effective as of January 2003 (Federal Aviation Regulations, 14 CFR Section 136.5).

In 1998, data collection was started for the development of a study plan to characterize ambient sound in the park. The project was designed to evaluate noise characteristics in the park with respect to noise from aircraft tour overflights. However, Section 806 of the National Parks Air Tour Management Act of 2000 permanently banned commercial air tours over the park, and the study was suspended after Phase I was completed. The 1998 data were the first noise data collected in the park. One-hour sound level measurements were taken at eight sites by Harris, Miller, Miller, and Hanson (1998), on one to three occasions each, in forest, tundra, and meadow habitats. Background level measurements were determined, and then intrusions from jets, other aircraft, and other human-based noises were noted. Background sounds in forested areas ranged from 25 decibels (dBA) for wind to 46 dBA for elk; from 26 dBA (wind) to 38 dBA (other animals) in meadow areas; and 27 dBA (wind) in tundra areas.

One-hour sound level measurements of 15 sites in Rocky Mountain National Park, taken to examine how to measure noise intrusions in national parks, provide additional baseline data with which to estimate the natural and current soundscapes of the park (Harris, Miller, Miller, and Hanson, Inc. 2001). Some undeveloped sites where wind in the foliage was heard were as low as 20 to 30 dBA). At other developed sites, intrusions into the natural soundscape occurred, including low levels of traffic noise (25 to 35 dBA), helicopter overflights (50 to 73 dBA), propeller aircraft (55 dBA), and jet overflights (35 to 50 dBA).

Noise levels vary between day and night in Rocky Mountain National Park. Because human activity mostly occurs during the day, noise levels in the park are higher then than at night. Night provides greater opportunity to experience the natural sounds in the park with less human influence.

The primary human-made sounds present in the park are noises associated with vehicles and campground use. Engines are a major source of human-caused sound in the park. These include automobiles, motorcycles, and trucks, aircraft, and generators. Other common sources of human-caused sound in the park include electronic devices such as radios and automobile horns, human vocalizations, and vehicle tires on roads. Human-caused sound is typically higher between May and September, corresponding with higher park visitation during these months.

WILDERNESS

The 1964 Wilderness Act defines wilderness:

"A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammelled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value."

In Rocky Mountain National Park, 94% of the park is recommended wilderness, 1% is designated wilderness, and the remaining 5% is classified as administrative, historic, and roads (see Figure 3.7). *NPS Management Policies* (NPS 2006b) states that all wilderness categories, including suitable, study, proposed, recommended, and designated, shall be treated as wilderness; thus, all categories of wilderness were considered in this analysis. The total wilderness area in Rocky Mountain National Park is 251,381 acres (NPS 2001a). Six U.S. Forest Service administered wilderness areas lie adjacent to the park, including Indian Peaks, 73,291 acres; Rawah, 73,068 acres; Comanche Peak, 66,791 acres; Never Summers, 20,747 acres; Neota, 9,924 acres, and; Cache la Poudre, 9,238 acres. A wilderness management objective for Rocky Mountain National Park is to cooperate and coordinate the management of the park's wilderness with management of the adjacent U.S. Forest Service wilderness areas. Information, techniques, and ideas will be freely shared and discussed that will lead to better protection and management of wilderness areas administered by both agencies (NPS 2001a).

All backcountry/wilderness areas of Rocky Mountain National Park are designated in one of four management classes based on the following criteria: type and amount of use, accessibility and challenge, opportunity for solitude, acceptable resource conditions, and management use. Table 3.3 presents some of the primary characteristics associated with each backcountry/wilderness management class.

National Park Service policy dictates that all management decisions affecting wilderness must be consistent with the minimum requirement concept, by completing a minimum requirement analysis on potential actions in wilderness. The minimum requirement analysis enables managers to examine and document whether a proposed management action is appropriate in wilderness and, if it is, what is the least intrusive equipment, regulation, or practice (minimum tool) that will achieve wilderness management

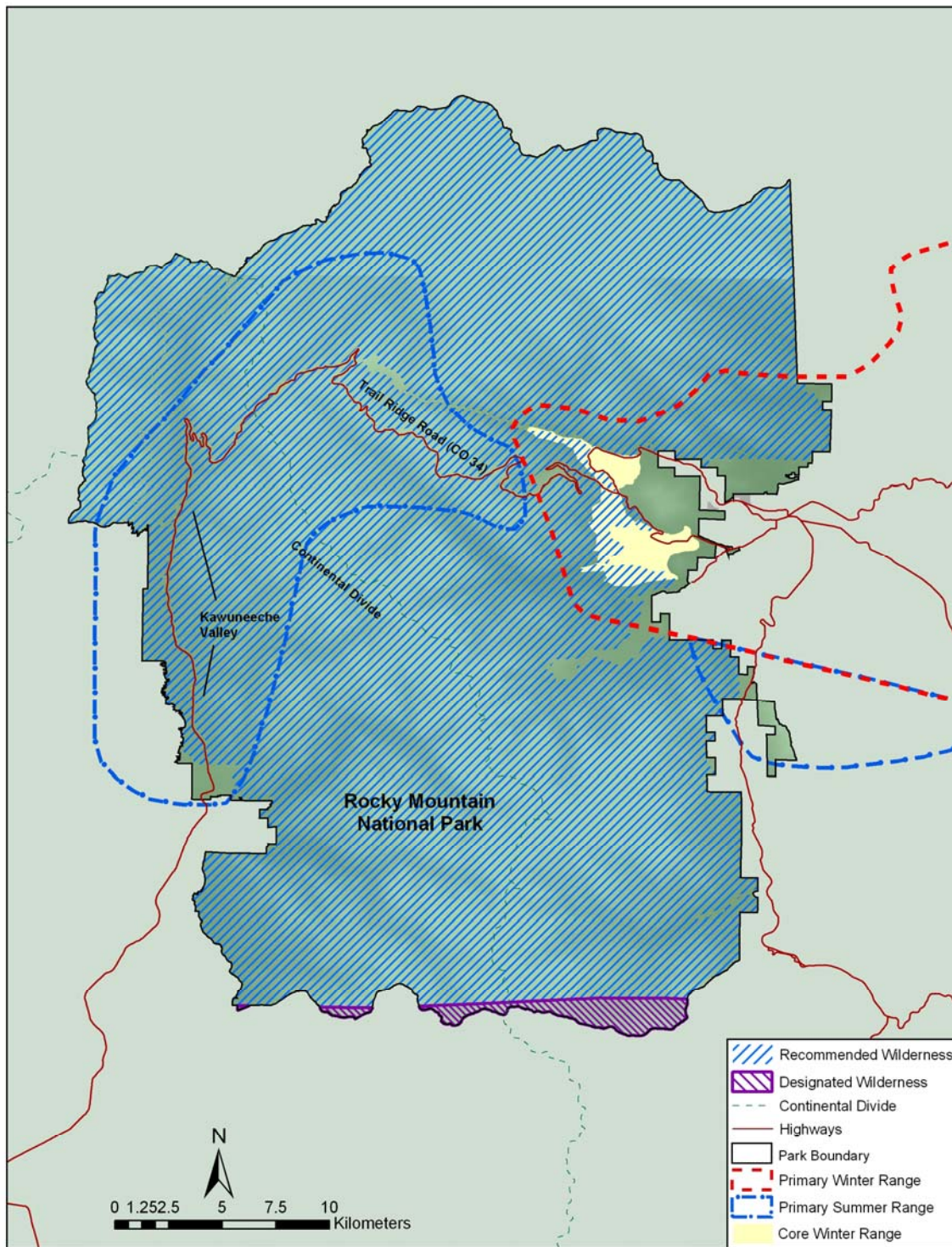


FIGURE 3.7: WILDERNESS TYPES IN ROCKY MOUNTAIN NATIONAL PARK

TABLE 3.3. ROCKY MOUNTAIN NATIONAL PARK WILDERNESS MANAGEMENT CLASSES

Class	RMNP Acreage	Public Use	Opportunity for Solitude	Management Use
1	170,236	Day use only; no stock use; no camping except for management activities and in winter (with restrictions)	Outstanding opportunity for solitude; natural sounds prevail	No designated or maintained trails; no signs or cairns; evidence of management is rare; mechanized equipment only during emergency operations or “absolutely critical” as determined by a minimum requirement analysis and approved by Superintendent
2	36,832	Low to moderate use; no stock use; area camping for seven or fewer persons allowed; no fires	High most of the year; moderate during summer; some noise interferes with natural sounds	No designated trails, but some designated routes; minimum cairns as necessary; no facilities; signs only as needed to protect resources and public safety; no motorized equipment except when approved with minimum requirement analysis
3	27,474	Moderate to high use; designated campsites; fires in campsites only; stock use on designated trails and camp sites only	Low to high depending on time of year, day of week, time of day, weather, and other factors	Facilities (e.g., privies, hitchrails, cabins, tent pads, signs) per minimum requirement concept; designated, formally constructed trails
4	23,313	High use; stock use on designated trails only; day use only (except eight designated camp areas)	Low to moderate depending on time of year, day of week, time of day, weather, and other factors	Facilities (e.g., privies, hitchrails, cabins, tent pads, signs) per minimum requirement concept; designated, formally constructed trails

objectives. The completion of this process assists managers in making informed and appropriate decisions concerning actions conducted in wilderness (NPS 2001a).

In wilderness, how a management action is carried out is as important, if not more important, than the end product. When determining minimum requirement, the potential disruption of wilderness resources and character will be considered before, and given significantly more weight than, economic efficiency and convenience. If a compromise of wilderness resources or character is unavoidable, only those actions that preserve wilderness character in the long term and/or have localized, short-term adverse impacts will be acceptable (NPS 2001a).

As stated in the park’s backcountry/wilderness management plan (NPS 2001a), stricter standards are used with regard to the use of motorized equipment and mechanical transport in non-emergency actions. In Class 1 areas of the park, hand tools and traditional practices are typically used. Motorized equipment and mechanical transport are not allowed, except during emergency operations or when “absolutely critical” for the protection of natural or cultural resources as determined on a case-by-case basis using a minimum requirement analysis and approved by the superintendent. In Classes 2, 3, and 4, hand tools and traditional practices are used whenever possible. Motorized equipment and mechanical transport are not routinely used, unless their use is first reviewed using the minimum requirement analysis or approved in an existing management plan (e.g., backcountry/wilderness management plan, fire management plan).

The elk winter range includes primarily Class 4 areas of wilderness, with some Class 1 and Class 3 areas. The elk summer range, which is at higher elevations, includes predominantly Class 1 areas, with some Class 3 and a few Class 4 areas.

SOCIOECONOMICS

The socioeconomic affected environment includes the socioeconomic impact area and the baseline conditions within that impact area. The primary impact area is Rocky Mountain National Park and the Estes Valley, including the town of Estes Park, in Larimer County because this is:

- The region in which the concentrations of elk are highest,
- The area in which visitation is most influenced by the presence of elk, and
- The area within which proposed actions will primarily take place.

The town of Grand Lake in Grand County on the west side of the park may also be affected; however, the magnitude of the effects from proposed actions would be very small. Therefore, the socioeconomic conditions of Grand Lake are not characterized in this chapter, but the effects on Grand Lake are analyzed qualitatively in Chapter 4, “Environmental Consequences.”

The major components of socioeconomic conditions in the Estes Valley include economics (employment, income, sales, tourism), demographics (population, age, ethnicity, housing), fiscal circumstances (budgets and operations for government agencies), and the social environment (rural nature, agriculture, mountain setting). Elk and vegetation in this primary impact area affect these socioeconomic conditions in various ways.

Current Economic Conditions and Trends

The economic conditions of the geographic area of effect are described through income and employment trends, characteristics and demographics of the labor force, and descriptions of the area’s major economic sectors, especially tourism and recreation.

Employment

The Estes Valley’s largest employers include the local school district, the Estes Park Medical Center, the Town of Estes Park government, the Estes Valley Recreation and Park District, the National Park Service, and the Harmony Foundation. The Estes Valley also has a notable construction sector that reflects the rapid growth in the area over the past 15 years. Large tourism and recreation employers include the Holiday Inn and YMCA of the Rockies (Town of Estes Park 2005b).

As shown in Table 3.4, tourism-related employment sectors dominate the Estes Valley economy, which centers on the Town of Estes Park and Rocky Mountain National Park.

The largest Estes Valley employment sectors are retail trade and arts, entertainment, and accommodation and food services, which together make up 43% of Estes Valley employment. These industries employ many people but do not pay high wages. Between 1990 and 2000, Estes Valley employment grew by about 50%. The bulk of the growth occurred in tourist-related, service-employment sectors.

The Estes Valley labor force has both a relatively low unemployment rate and low participation rate, indicative of a strong economy and with a disproportionate number of retirees.

TABLE 3.4: EMPLOYMENT BY INDUSTRY, ESTES VALLEY, 1990 AND 2000

Industry	Number of Persons 1990	Percent of Total 1990	Number of Persons 2000	Percent of Total 2000
Agriculture, forestry, fishing and hunting	38	1	28	1
Mining	0	0	17	0
Construction	206	7	390	9
Manufacturing	105	3	261	6
Wholesale trade	58	2	55	1
Retail trade	658	22	736	16
Transportation, warehousing, and utilities	114	4	151	3
Information	NA	0	124	3
Finance, insurance, and real estate	234	8	280	6
Professional services	129	4	320	7
Educational, health, and social services	501	17	628	14
Arts, entertainment, food, and accommodation services	130	4	1,243	27
Other services	649	22	202	4
Public administration	195	6	120	3
Total Employment	3,017	100	4,555	100

Source: U.S. Census Bureau (2001)

Employment fluctuates by season in the Estes Valley. Monthly employment data are available only at the county level, so Larimer County, Colorado, serves as a proxy for the Estes Valley. Larimer County seasonally employed more individuals in all industries and in the accommodation and food services sector in the summer months of 2004, partially reflecting the Estes Valley's dominant tourism industry. Rocky Mountain National Park uses roughly 1,600 volunteers each year for various tasks, which would not be evident in the employment data (NPS 2005I). Most of those volunteers work in the more temperate summer and autumn months, many on programs related to elk, such as the Bugle Corps.

Tourism and Recreation

Tourism and recreation is the largest industry in the Estes Valley, evidenced by relative prominence of the retail, service, construction, and related economic sectors that benefit from visitors who vacation at Rocky Mountain National Park and in Estes Park. In the employment and income data presented earlier, direct tourism and recreation account for more than 40% of the Estes Valley economy.

Several amenities exist in the Estes Valley area, all of which draw visitors to come to and remain in the area. In addition to Rocky Mountain National Park, these recreational opportunities

include Roosevelt National Forest; the shopping districts of the Town of Estes Park; the facilities of the Estes Valley Recreation and Park District facilities, including two golf courses; and the Big Thompson River. Additionally, the Town of Estes Park holds events year-round that draw visitors, such as ethnic festivals, gallery tours, the Estes Park Wool Market, the Rooftop Rodeo, and Elk Fest.

The Contribution of Rocky Mountain National Park to the Local Economy

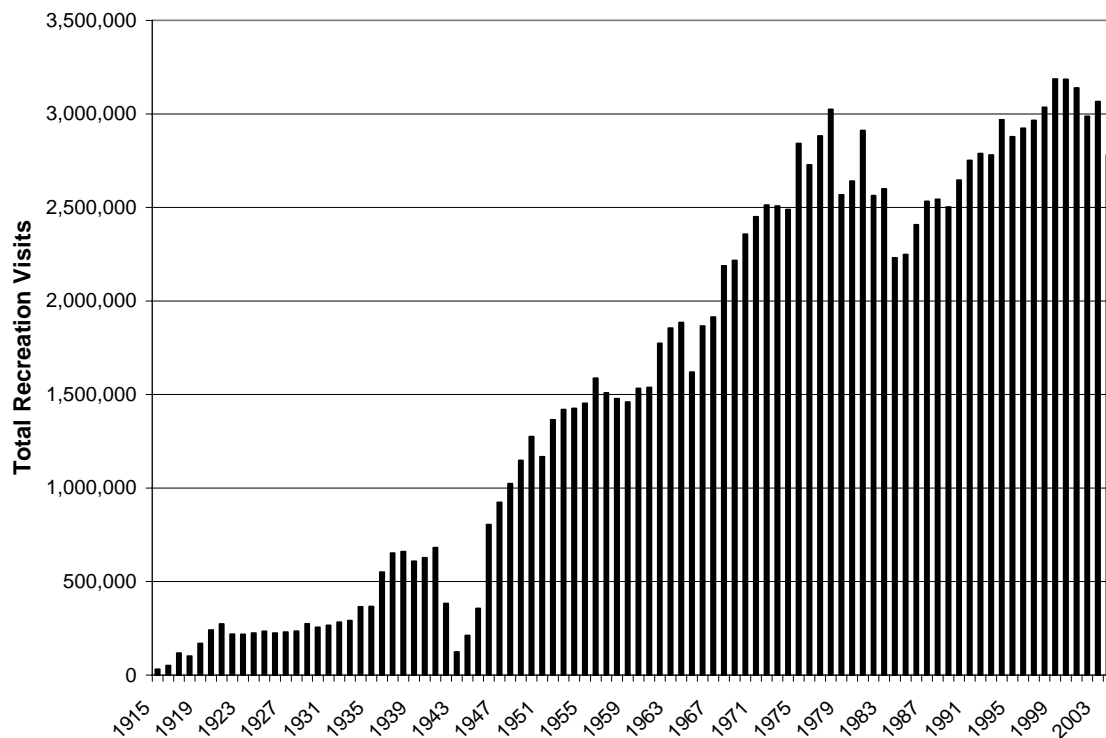
The National Park Service estimated that visitation to Rocky Mountain National Park approximated 2.8 million in 2004; Figure 3.8 shows the trend in overall recreation visits to Rocky Mountain National Park since 1915. Table 3.5, below, shows that most visitors enter Rocky Mountain National Park through Estes Park, rather than through Grand Lake. As illustrated by the table, in 2003, this gate was used by 71% of visitors.

Rocky Mountain National Park's busiest months each year are June through September. September has consistently accounted for between 14% and 16% of total annual visitation (NPS 2005k). Forty-five percent of visitors to the park are non-local day visitors, from areas outside the study area. Not included in this number are the non-local visitors who stay overnight in the park. Overnight visitors account for 6.5% (or 189,336) of total annual visitation, and though the information is not available to determine what portion are non-local, the proportion is likely similar to the proportion of non-local day visitors. Of these non-local visitors, most come from Denver, Boulder, Fort Collins, and Texas.

The National Park Service, in concert with Michigan State University, created the Money Generation Model (MGM) to assess the economic impacts of the Service's park units, including Rocky Mountain National Park, on their local areas. In 2003, the MGM estimated that Rocky Mountain National Park's 3.1 million recreation visits were split into the following categories: 10% local visitor day trips; 45% non-local visitor day trips; 35% hotel stay visits; and 10% camping stay visits (NPS 2005e). Local is defined as Larimer County.

The MGM calculated Rocky Mountain National Park's total annual economic impact on the local area as \$204 million in sales, \$69 million in personal income, and nearly 5,000 jobs (NPS 2005e). This included direct economic effects of \$154 million in direct sales of goods and services, \$52 million in personal income, and 4,200 jobs for the local area. Those sales, income, and jobs reverberated through the economy, generating \$50 million in secondary sales, \$17 million in secondary personal income, and another 740 secondary jobs. Secondary sales, income, and jobs are those that result from rounds of spending that occur subsequent to the initial spending by visitors (e.g., personal consumption, expenditures of local employees).

Part of Rocky Mountain National Park's economic contribution stems from its 19 concessioner contracts with companies that operate in Rocky Mountain National Park. They provide horseback riding on livery trails, wood sales, guided rock climbing trips, and retail sales at the Trail Ridge Store. These concessioners employed roughly 150 persons and generated \$4.8 million in gross sales in 2004 (Hannon 2005).



Source: National Park Service, Visitation Statistics, Public Use Statistics Office,
<http://www2.nature.nps.gov/stats/>, July 2005.

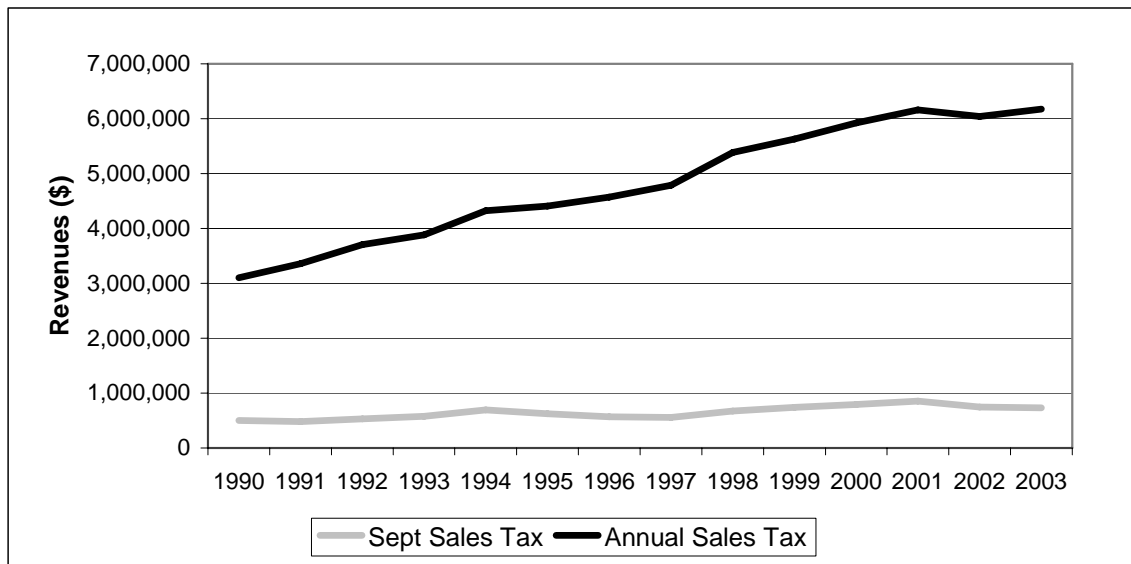
FIGURE 3.8: TOTAL RECREATION VISITS TO ROCKY MOUNTAIN NATIONAL PARK, 1915 THROUGH 2004

TABLE 3.5: RECREATION VISITS THROUGH ROCKY MOUNTAIN NATIONAL PARK'S ENTRANCES IN THOUSANDS, 1996 THROUGH 2003

	<u>Estes Park</u>	<u>Grand Lake</u>	<u>Other Entrances</u>	<u>Total Visits</u>	<u>Annual Change</u>
1996	2,186	478	194	2,857	NA
1997	2,185	479	221	2,885	1.0%
1998	2,239	498	190	2,927	1.5%
1999	2,285	499	304	3,089	5.5%
2000	2,324	449	316	3,088	0.0%
2001	2,255	433	350	3,038	-1.6%
2002	2,102	435	355	2,891	-4.8%
2003	2,138	460	395	2,993	3.5%

Source: National Park Service, Visitation Statistics, Public Use Statistics Office,
<http://www2.nature.nps.gov/stats/>, July 2005.

The Town of Estes Park collects a 4% sales tax on retail sales and on accommodation and food services, among other services. Figure 3.9 highlights the town's annual and September tax collections from 1990 through 2003.



Source: Town of Estes Park, Finance Department, sales tax collection data obtained in 2004.

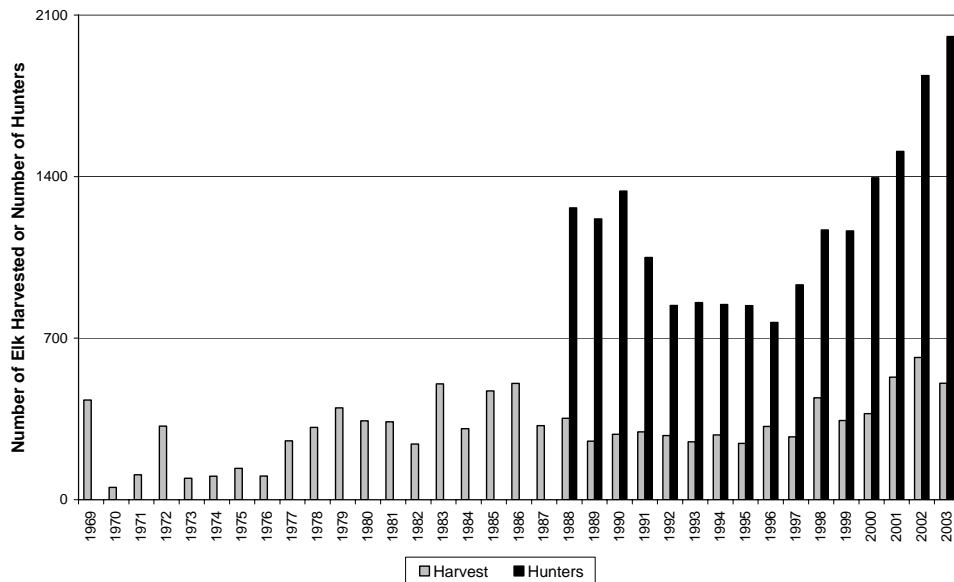
FIGURE 3.9: TOWN OF ESTES PARK ANNUAL AND SEPTEMBER SALES TAX COLLECTIONS, 1990 THROUGH 2003

The town's annual sales tax collections rose steadily from 1990 through 2003. Sales in September (the peak season for elk viewing) remained rather steady over this period, causing its share of annual sales tax collections to decline from 16% to 12% between 1990 and 2003. Though the proportion of annual visitation to Rocky Mountain National Park captured in September has remained steady over the years, sales to those visitors as a proportion of annual sales have apparently declined. These data suggest that an increasing proportion of the September visitors do not spend the night. Thus, the positive economic impacts of the elk are probably not increasing at the same rate as overall economic impacts of the park.

Lodging and accommodations, retail and gifts, and restaurants make up the largest portion of sales tax collections in Estes Park. The town has a wide range of lodging options. These include almost 30 hotels and motels, 10 bed and breakfast accommodations, more than 40 cabins and cottages, more than 10 inns and lodges, about 20 rental condominiums and companies offering rentals, and seven campgrounds and recreational vehicle parks (Town of Estes Park 2005a). The town's occupancy rate in September likewise dropped from 80% to 64% during 1999 to 2003.

Impacts of Hunting on the Local Economy

Hunting is an important recreational activity in the Estes Valley and Larimer County. Figure 3.10 presents data on the number of elk harvested and the number of hunters around Rocky Mountain National Park in the vicinity of the Estes Valley. The data spanning 1969 through 2004 are provided for Colorado Division of Wildlife Game Management Unit 20 around Estes Park and Game Management Unit 18 around Grand Lake. Figure 3.11 shows the game management units near the park.



Source: Colorado Division of Wildlife. 2005. Big game hunting season recap summaries and harvest survey statistics, <http://wildlife.state.co.us/huntrecap/>, July 2005.

FIGURE 3.10: ELK HARVESTED AND HUNTERS IN THE FIELD IN GAME MANAGEMENT UNIT 20, ESTES PARK, 1969 THROUGH 2004

In Game Management Unit 20, the number of elk harvested has been 300 to 600 animals since 1969. The economic impact of hunting is much greater on the west side of Rocky Mountain National Park; the number of hunters around Grand Lake is more than twice that of Estes Park. Hunter numbers appear steady around Grand Lake, but hunter numbers around Estes Park rose substantially from the late 1990s through 2004. The Colorado Division of Wildlife estimated that hunters spent roughly 16,500 days hunting around Estes Park, with no specification for residents and non-residents (CDOW 2005b). Using the Colorado Division of Wildlife’s 2004 hunting economic impact model, it is estimated that hunters around Estes Park spend about \$50 per day, and hunters around Grand Lake spend about \$70 per day, totaling \$825,000 and \$1.7 million in direct economic effects from hunting in the two areas, respectively (BBC 2004).

Fiscal Conditions of Government Entities

Several government agencies other than the National Park Service would be financially affected by any elk and vegetation management actions. These agencies include the Town of Estes Park, the Estes Valley Recreation and Park District, and the Colorado Division of Wildlife. It is anticipated that any financial impacts on the Town of Grand Lake would be minimal, and its fiscal conditions are not analyzed. Also, it is unlikely that any impacts from the alternatives would affect the U.S. Forest Service or the Bureau of Land Management, since their visitation is probably not driven by the management actions in the alternatives. The National Park Service’s budget for revenues, expenditures, and capital investments in Rocky Mountain National Park is highlighted in the “Park Operations” section. The National Park Service estimates that it currently spends less than 1% of its budget directly on the management of elk and vegetation in the park, out of a 2004 budget of \$20.4 million (Johnson 2005).

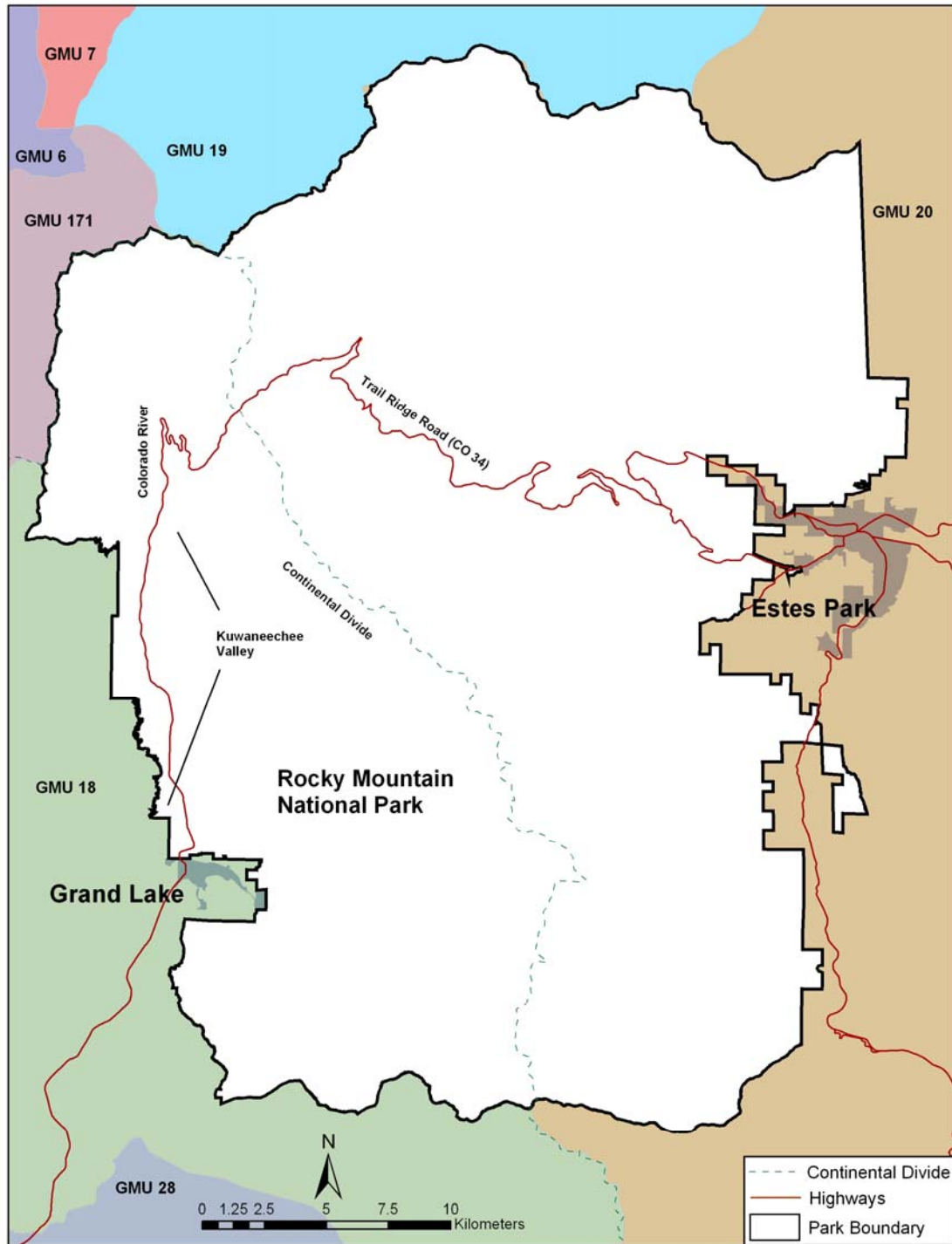


FIGURE 3.11: GAME MANAGEMENT UNITS IN THE VICINITY OF ROCKY MOUNTAIN NATIONAL PARK

Town of Estes Park

The 2002 budget for the Town of Estes Park is summarized in Table 3.6. The town collects most of its revenues through sales and use taxes within town limits, and it devotes a large portion of its expenditures to culture and recreation, reflecting the tourism and recreation focus of the area. The town employs roughly 100 full-time individuals and 50 seasonal persons. Officials were unable to estimate costs for managing elk and repairing any damage they may cause to town property, but implied that expenditures were minimal (Feagans 2005).

Estes Valley Recreation and Park District

The Estes Valley Recreation and Park District's 2005 budget is presented in Table 3.7. This agency derives almost all its revenues from user fees at its recreational facilities and devotes nearly all its budget to maintenance and operations. They employ 16 individuals full-time year-round and an additional 60 to 80 seasonal employees each summer. An estimated \$12,000 to \$14,000 (approximately 0.5% of the district's budget) were spent on managing elk and repairing any damage they cause to district property in 1999 (Gengler 2005).

Colorado Division of Wildlife

The Colorado Division of Wildlife's fiscal year 2002-2003 budget is presented in Table 3.8. The division generates most of its revenues through licensing fees with some assistance from federal and state funds, and it devotes more than half its expenditures to wildlife and habitat management. The Colorado Division of Wildlife employs roughly 650 individuals throughout Colorado. Much of the division's expenditures within the Estes Valley involve elk and other wildlife management.

Contribution of Elk to the Current Economic Conditions

The elk in and around Rocky Mountain National Park contribute to the economy of the Estes Valley in several important ways. Most notably, elk contribute to the draw that brings visitors to Rocky Mountain National Park and the surrounding areas. Elk also affect the economy through landscaping damage and repair on private and public property, including agricultural lands; traffic congestion and accidents; property values; and quality of life for local residents. These economic effects are both positive and negative.

Interviews with 29 representative local residents and industry representatives (stakeholder interviews) and surveys of visitors to the area were the primary tools used to characterize and quantify, where possible, these economic impacts in the Estes Valley.

Visitation to the Area

Stakeholder interviews suggested that elk are an important element of the overall scenery and nature of Rocky Mountain National Park that attracts millions of visitors each year (Harvey Economics 2005). Elk's contribution to that visitor draw increases in September, during the elk rutting and bugling season. In one study, between 20% and 30% of Rocky Mountain National Park visitors indicated that they would visit the park less often if they were less likely to see or hear elk (Fix et al. 2004). In another study, when asked to note the primary motivations to visit Rocky Mountain National Park, approximately 70% of visitors to Rocky Mountain National Park stated that they came to view elk, among other reasons (Cordova 2000b).

TABLE 3.6: 2002 BUDGET FOR THE TOWN OF ESTES PARK

<u>Budget Item</u>	<u>2002 Dollars (\$)</u>
Revenues	
Sales and use tax	\$6,261,334
Other taxes	\$403,477
Licenses, permits, fees and charges	\$1,630,479
Intergovernmental revenue	\$1,489,967
Transfers from enterprises	\$1,158,216
Total Revenues	\$10,943,473
Operating Expenditures	
Public safety	\$2,520,407
Culture and recreation	\$1,820,334
General government and other	\$3,230,165
Total Operating Expenditures	\$7,570,906
Transfers to other governments or enterprises	\$2,542,834
Capital Outlay	\$2,999,386
Principal Payments	\$175,167
Interest Payments	\$236,573
Debt Outstanding	\$3,248,741

Source: Colorado Department of Local Affairs, Municipal Budgets 2002,
<http://www.dola.state.co.us/LGS/TA/compendium.htm>, July 2005.

TABLE 3.7: 2005 BUDGET FOR THE ESTES VALLEY RECREATION AND PARK DISTRICT

<u>Budget Item</u>	<u>2005 Dollars (\$)</u>
Revenues	
General fund	\$392,642
Recreation, parks and trails	\$301,498
Aquatics	\$91,350
Golf courses	\$1,537,777
Marina	\$204,735
Transfer from Conservation Trust Fund	\$48,500
Total Revenues	\$2,576,502
Operating Expenditures	
Maintenance and operations	\$2,317,132
Contingency	\$21,032
Total Operating Expenditures	\$2,338,164
Transfer to Conservation Trust Fund	\$105,000
Capital Expenses	\$179,000

Source: EVRPD 2005.

TABLE 3.8: BUDGET FOR COLORADO DIVISION OF WILDLIFE, FISCAL YEAR 2002-2003

Budget Item	2003 Dollars (\$)
Revenues	
License revenue	\$60,654,392
Federal and state aid and grants	\$21,735,437
Interest	\$2,949,021
Goods and services	\$876,305
Other	\$763,525
Total Revenues	\$86,978,680
Expenditures	
Wildlife habitat and species mgmt	\$20,649,693
Wildlife recreation	\$33,087,488
Wildlife education and information	\$9,567,018
Responsive management	\$27,285,450
Total Expenditures	\$90,589,649

Source: Colorado Division of Wildlife, 2003 Annual Report,
<http://wildlife.state.co.us/AnnualReport/2003/report.pdf>, July 2005

Based on these inputs, elk contribute significantly to the draw for visitors in September and to a lesser degree throughout the rest of the year. Typically, about 15% of visitors to Rocky Mountain National Park visit in September (NPS 2005k). Since 70% of the draw for visitors in September is due directly to the elk, then approximately 11% of overall visitation is attributable to elk, not including their added influence for visitors to come to Rocky Mountain National Park throughout the rest of the year. That rate of influence indicates that elk generate up to \$30 million in sales, \$10 million in personal income, and 750 jobs in the Estes Valley each year. The elk are also then responsible for 15% of the town's sales tax revenue, or about \$900,000 each year.

Landscaping Damage

The effects of elk on the Estes Valley economy extend beyond the attraction of visitors. The elk, especially in their currently high and concentrated numbers within the Estes Valley, browse landscaping plants and grass, consequently damaging those landscaped areas on both public and private lands. The Estes Valley Recreation and Park District estimates that elk cost the District \$12,000 to \$14,000 in management and landscaping maintenance each year (Gengler 2005). The Town of Estes Park spends very little each year to repair landscaping damage on town property (Feagans 2005).

While landscaping damage is a negative impact for the local economy, it is also a benefit for local landscaping companies that generate more work and income by relandscaping properties. One landscaping company estimated that it generates about \$70,000 annually in gross sales from installing elk-proof landscaping fence and selling shrubs and plants due to elk damage (Dudzinski 2003). If such revenues were consistent across the five landscaping companies in Estes Park, elk landscaping damage costs local residents as much as \$350,000 each year, benefiting those local landscaping companies.

There is one operating cattle ranch within the primary impact area, and the owner indicated that the ranch accommodates the presence of browsing elk by reducing its herd to the carrying capacity of the land for grazing. The owner estimated that the ranch could run 50 to 100

additional cattle each year if the elk did not graze his land. This rancher's opportunity cost amounts to roughly \$90,000 to \$180,000 in lost revenues each year due to the elk (Adams 2003).

Switzer-Land Alpacas is an 8-acre farm located on the Mary's Lake Road in Estes Park. The farm has a herd of about 50 alpacas of various breeds and employs one full-time and two part time staff members. The main activities of the farm include selling and breeding alpacas. The farm manager reported that there are no impacts from elk to the alpacas themselves or to the business. The elk and the alpacas graze on the grass on the farm, but the amount that the elk eat does not affect the amount available for the alpacas (Beck 2006).

Private landowners in the vicinity sell permits to hunt on their property. This generates revenue for those landowners, and it is not expected that there would be a decrease in landowners' ability to sell permits as a result in the reductions in the elk population that are considered in this plan.

Traffic Congestion and Accidents

Elk also cause traffic congestion and have been involved in elk-automobile accidents in Rocky Mountain National Park and the Estes Valley. Colorado Department of Transportation (CDOT) traffic counters at the intersection of U.S. Highways 34 and 36 counted more than six million vehicles in 2004 (CDOT 2005). In the confines of Estes Park and the valleys leading into Rocky Mountain National Park, such traffic levels would likely cause congestion with or without elk; therefore, quantifying the impact of elk on traffic volumes alone is not attempted here.

The Colorado Department of Transportation tracks traffic accidents in the Estes Valley. The statistics for 1993 through 2002 show that accidents involving wild animals have generally increased concurrently with the area's rise in residency and tourism in the area, as have the total number of automobile accidents. No explicit information is available about accidents involving elk.

A stakeholder interview with an auto body shop owner in Estes Park lent insight into the costs of elk-automobile collisions in the Estes Valley. He indicated that his shop works on an average of one automobile involved in an elk collision each month, or about 12 automobiles per year (Thoms 2004). He estimated that each collision costs the automobile owner about \$2,000 in bodywork, which equates to roughly \$24,000 each year in revenue to the body shop from elk-related traffic accidents. There are three auto body shops in Estes Park, and if each performs about the same amount of work on elk-related automobile collisions, the total cost to automobile owners from elk-related accidents, and revenues for these auto body shops, could be as much as \$75,000 per year.

Elk Influence on the Local Quality of Life

Elk also influence the Estes Valley through a contribution to quality of life for local residents and, through that quality of life, by sustaining or improving residential and commercial property values. The median price of owner-occupied homes in the Estes Valley rose by 125% between 1990 and 2000. Housing prices are affected by many factors, including economic growth, demand for and supply of housing, new housing developments, and quality of life. The distinct effect of elk on property values is not estimated here. However, in the stakeholder interviews conducted for this study, about 70% of residents interviewed indicated that elk are an important part of the quality of life of the Estes Valley. These respondents also often noted, though, that elk are not a primary reason for which new residents come to live and work in the Estes Valley.

PUBLIC HEALTH AND SAFETY

Rocky Mountain National Park is responsible for maintaining safe conditions that protect the health and safety of employees and the public in the park. Statutory and regulatory provisions applicable to units of the National Park Service require the park to not only provide safe facilities, utilities, and grounds within the park but also promote safety in park program and project operations. While the park is not responsible for safety in nearby towns such as Estes Park or Grand Lake, it recognizes that in-park elk management actions may impact safety in town.

Health and Safety Concerns Related to Elk and Elk Management

Interactions between Elk and Visitors

Like all wild animals, elk behavior can be unpredictable. Humans who approach too closely may trigger defensive behavior. Reports compiled from the park's Elk Bugle Corps volunteers indicate an average of three to five incidents per year involving charging bulls (commonly during the autumn rut) and approximately one per year of cows protecting newborn calves in the June calving season (Langdon 2004a). These incidents represent only what has been reported during times that volunteers are present. Actual numbers may be higher. So far, these incidents have resulted in no human injuries (Pettibone 2005). However, three volunteers have been injured while on elk-viewing duty since 1990: one was bitten by a dog and two sustained injuries from tripping (Langdon 2005d).

The most common locations for incidents are in or near Horseshoe Park, Beaver Meadows, and Moraine Park, the large meadows bisected by roads in the eastern part of the park, so staff and volunteers take extra precautions to reduce such incidents in these areas. Despite warning signs, volunteers and rangers intervene nearly every evening to return visitors to a safe distance from elk, and visitors have been known to physically fight over maintaining a safe distance from elk (Langdon 2005d). Visitors can also be aggressive toward other visitors who they perceive are interfering with their elk viewing opportunities. Ideally, three rangers assisted by Elk Bugle Patrol volunteers would patrol these three meadows every evening during the autumn rutting season, from the end of August to the end of October. Budget restrictions currently limit the park to assigning two rangers to this duty each evening, the minimum to maintain acceptable visitor safety (Langdon 2004a). Budget projections for the next few years suggest that the staffing situation, and therefore visitor safety in and around the meadows, will remain unchanged.

Protecting visitors places staff and volunteers at risk. Traffic congestion at the meadows increases the risk of vehicle collisions and associated personal injuries; Elk Bugle Corps volunteers who direct traffic are particularly vulnerable. Volunteers performing crowd control are at risk from nearby elk (Langdon 2004a). When the elk are easily visible along the roadway in meadows and visitor levels along the roadway and traffic become unsafe, rangers sometimes herd the elk away by horseback for visitor and traffic safety. Risks to rangers include falls from horses and elk charges.

The Rocky Mountain National Park communications center reports three collisions between elk and motor vehicles in 2004 (out of 89 vehicle accidents), occurring on 19 July, 19 August, and 17 November. In all three cases, the vehicle occupants were uninjured, and injuries to elk were minimal (Holien 2005a, 2005c). This compares to four collisions between deer and motor vehicles in 2004 (Holien 2005b).

Chronic Wasting Disease

Although existing evidence suggests that chronic wasting disease is not transmissible to humans (Belay et al. 2004), the Colorado Division of Wildlife recommends that hunters take precautions, including not handling or consuming elk or deer that appear sick, and not consuming brain, spinal cord, eyes, spleen, tonsils, pancreas, or lymph nodes of harvested animals (CDOW 2003a). The park's interim operating plan for handling deer and elk provides safety precautions for personnel monitoring, treating, or handling elk from infected areas (NPS 2001g).

Within the park, those most likely to face exposure to chronic wasting disease are employees and volunteers working with carcasses of potentially infected deer and elk, as when taking tissue samples for testing or when disposing of carcasses. Because hunting is illegal within the park, park visitors are unlikely to directly encounter diseased elk. However, because elk freely cross park boundaries, hunters (who often consume meat from the elk they take) in Game Management Unit 20 (surrounding the park's eastern boundary) and Game Management Unit 18 (surrounding the park's western boundary) could be affected by the park's elk management policies. On average over the past six years, Game Management Unit 20 has averaged 1759 elk hunters annually, and Game Management Unit 18 has averaged 4974 elk hunters annually. See Tables 3.9 and 3.10 for the numbers of elk and deer hunters each year from 1999 through 2004.

TABLE 3.9: GAME MANAGEMENT UNIT 20 HUNTERS

Year	Elk	Deer
2004	2,652	2,197
2003	2,007	1,902
2002	1,838	1,443
2001	1,498	1,226
2000	1,393	1,002
1999	1,165	910

Source: Colorado Division of Wildlife website <http://wildlife.state.co.us>

TABLE 3.10: GAME MANAGEMENT UNIT 18 HUNTERS

Year	Elk	Deer
2004	5,218	2,535
2003	5,195	1,720
2002	4,457	1,401
2001	4,356	1,167
2000	5,167	2,069
1999	5,449	1,608

Source: Colorado Division of Wildlife website <http://wildlife.state.co.us>

No chronic wasting disease statistics are available for the park, so chronic wasting disease prevalence is estimated from harvest estimates in adjacent Game Management Units. Prior to 2002, chronic wasting disease prevalence in elk was less than 1% in all Game Management Units where it was known to occur. Estimates in more recent years have had higher prevalence estimates. Elk Data Analysis Unit E-9 (Game Management Unit 20) which is adjacent to most of the east side of the park had the second highest chronic wasting disease prevalence estimate during the 2005-2006 hunting season: 2.6%, with a 95% confidence level ranging from 0.3% to 4.8% (Miller 2006). This was higher than the three-year average from 2003-2005 of 1.7%, with a 95% confidence interval of 0.9% to 2.5% (Miller 2006). Elk Data Analysis Unit E-8 (Game Management Unit 18, 181) which is adjacent to most of the west side of the park had the third highest chronic wasting disease prevalence estimate during the 2005-2006 hunting season: 0.5%, with a 95% confidence level ranging from 0.0% to 1.5% (Miller 2006). This was lower than the three-year average from 2003-2005 of 1.2%, with a 95% confidence interval of 0.4% to 2.1%

[\(Miller 2006\). Currently, park staff lethally take only those elk showing symptoms consistent with chronic wasting disease. Staff took one elk in 1981, 1998, and 2002, six in 2003, three in 2004, eight in 2005 and none in 2006. In addition, staff tests elk carcasses for chronic wasting disease. The carcasses tested were three in 2001, 15 in 2002, 26 in 2003, 16 in 2004, 12 in 2005 and nine in 2006 \(Watry 2007\).](#) Primary concerns include accidental human exposure to wildlife drugs when performing the lethal removal, and handling of elk that may have chronic wasting disease. To reduce risks, these operations take place during hours when visitor activities are low, after extensive training in the use of wildlife pharmaceuticals and wildlife handling, and staff follow safety procedures when handling elk in areas where chronic wasting disease is present (NPS 2001g). To date, no staff members have been injured in such operations.

Health and Safety Concerns Related to Vegetation and Vegetation Management

Since 1935, 26 plots totaling 12 acres of willow stands, aspen clones, and other vegetative communities have been fenced in research projects to determine the effectiveness of such protective measures against over-browsing. Safety concerns include lacerations, bruises, and crush injuries during installation and maintenance, as well as potential injuries from unintended contact with fences by unwary visitors or staff. Injuries could also occur when releasing animals that manage to enter the enclosures and are unable to get out. No recorded injuries have occurred related to fence installation and maintenance or to freeing trapped animals.

VISITOR USE AND EXPERIENCE

Rocky Mountain National Park covers 265,461 acres in the Front Range of northern Colorado. The park's 2,988,475 visitors in 2002 ranked sixth among national parks. Visitors numbered 3,067,256 in 2003 and 2,781,899 in 2004, with 2,768,717 forecast for 2005 (NPS 2004g, NPS 2005f). As shown in Figure 3.12, the number of visits typically peaks in July and August (678,086 and 626,473, respectively, in 2003 and 633,725 and 561,193 in 2004) then drops over the next three months (465,941; 262,699; and 69,681 in 2003, 407,864; 200,180; and 52,173 in 2004) (NPS 2005f). The busiest weekend of the year often corresponds with the Estes Park Elk Festival in early autumn.

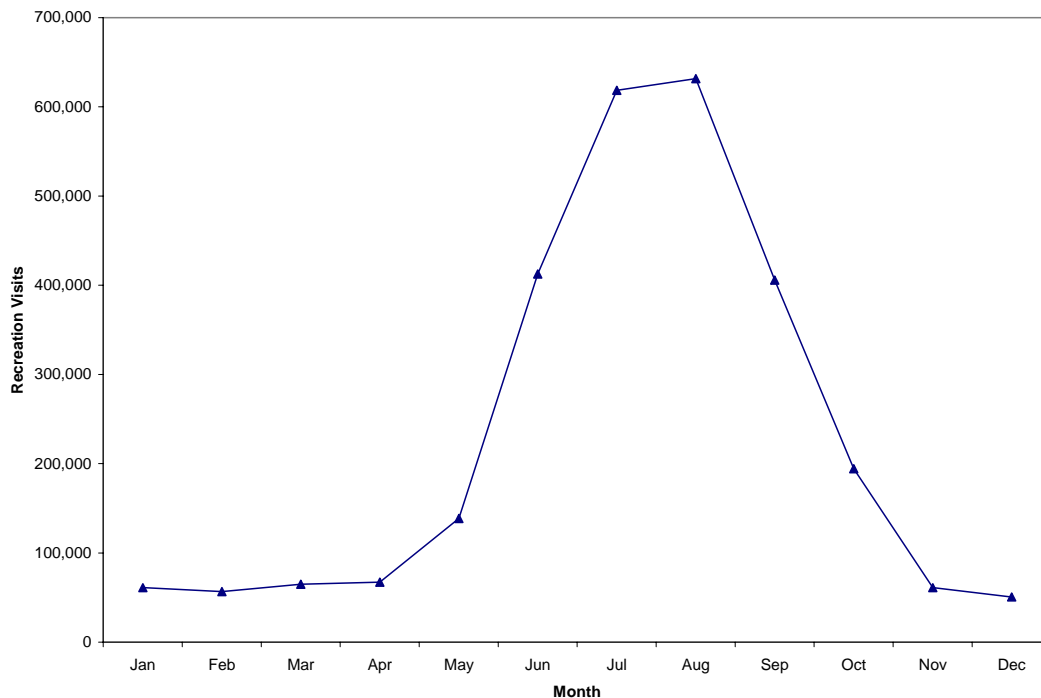


FIGURE 3.12: AVERAGE ROCKY MOUNTAIN NATIONAL PARK RECREATION VISITS BY MONTH, 1979 - 2003

Approximately 70% of visitors access the park through the east entrance, near the town of Estes Park (NPS 2005i). The town offers a wide range of tourist attractions, including hotels, restaurants, shops, golf, wildlife viewing, and special events, including the Estes Park Elk Festival in late September or early October. The nearby Arapahoe and Roosevelt National Forests allow multiple outdoor activities such as camping, hiking, rock climbing, mountain biking, off-road vehicle riding, wildlife viewing, hunting, skiing, and snowmobiling. Another 15% enter at the west entrance near Grand Lake, and the remaining entrances admit another 15% of visitors (NPS 2005i). Near the park's west entrance, visitors can enjoy five major reservoirs at the Arapahoe National Recreation Area or visit Grand Lake, the largest glacial lake in Colorado. Approximately 500,000 Rocky Mountain National Park visitors make the trip from Estes Park to the Grand Lake area each year when Trail Ridge Parkway is open, generally late May to early October (Town of Grand Lake 2005).

The National Park Service does not track where visitors go once within the park; however, the park's primary attractions are its scenery and wildlife. A survey during 1994 and 1995 found that

91.7% of visitors rated natural scenery as an extremely important park feature, and 83.1% rated wildlife as extremely important (NPS 1995). In a visitor survey in September and October 1999, the two most common reasons for visiting the park were to view wildlife (74.3%) and to view mountain scenery (73.1%). Fall is the favorite season for elk viewing (Johnson and Monello 2001); 66% of those visiting the park then did so primarily to view elk (Cordova 2000b). Many visitors tell park staff that they enjoy seeing the “tame” elk (Langdon 2005d), but perhaps as often, visitors comment that elk do not seem as wild as they should be (Muenchrath 2006).

The most popular elk viewing areas include Horseshoe Park, Moraine Park, and Upper Beaver Meadows on the park's east side. Aspen and willow communities in all three are severely impacted by elk browsing, and even the least impacted areas in the eastern winter range show visible signs of damage (Ronca 2005d). Areas in the Kawuneeche Valley such as Harbison Meadow and the Holzwarth Ranch Meadow are favorite viewing areas on the west side; damage to vegetation in Kawuneeche Valley is becoming increasingly visible (Ronca 2005d). Cub Lake Trail is popular with visitors willing to hike for elk viewing (Apt 2001).

Popular summer activities include not only viewing wildlife and scenery but also hiking, camping, climbing, fishing, mountaineering, and horseback riding on nearly 360 miles of trails. Campers have nearly 600 sites accessible by car, while backcountry visitors have another 208 sites available; in 2004, car-accessible campgrounds hosted 153,855 visitors, and backcountry campgrounds hosted 26,522 (NPS 2005f). Wintertime activities are primarily cross-country skiing and snowshoeing in the west and snowshoeing in the east. Sledding areas at Hidden Valley and Bear Lake receive heavy use on weekends (NPS 2005h).

Many people visit the park in autumn to enjoy the colorful foliage, particularly aspen, an activity so popular that news media along the Front Range report where leaves are likely to be near peak color during upcoming weekends. In some areas, the effects of elk are pronounced enough that visitors have noticed and commented on the over-browsing of aspen and willow. Many popular facilities in the park, including the Moraine Park Museum, the Moraine Park Campground, and the Sheep Lakes Information Station, are near experimental exclosures to assess effectiveness of fencing at protecting vegetation (Langdon 2005d). Park-wide, the visitor centers receive six to 12 questions per day about the damage to aspen trees in the lower meadows (Langdon 2005c). Similar numbers of visitors ask questions about the fencing around selected aspen stands where park resource managers are assessing the affects of protecting vegetation from elk; almost all are curious rather than concerned (Langdon 2005c). Visitors surveyed in 1999 were evenly split on whether to use fencing to keep elk away from sensitive vegetation (Cordova 2000b). Three years later, another survey found support as high as 60% for small-scale fencing lasting five to 25 years, dropping to 40% support for large-scale fencing lasting 30 to 50 years (Fix et al. 2004).

Some visitors are aware of the impact that elk overpopulation has on the park's flora; others place greater value on easy viewing of elk. In a 1999 survey, most visitors (72.4%) did not worry about the problems that elk may cause (Cordova 2000b). However, Fix et al. found that up to 90% of those surveyed in 2002 agreed with the statement “If natural conditions dictate there should be fewer elk in the park, the elk herd should be reduced,” and “It is acceptable to reduce the size of the elk herd to ensure that aspen and willow regenerate.” This would appear to indicate that visitors may not be readily aware of the physical evidence of vegetation damage, but when told by park managers that a problem exists, agree that management actions should be taken.

Many visitors want to see large groups of rutting elk in meadows near roads and listen to the bugling, despite complaints about the associated traffic congestion as visitors pull off the roads along these meadows. Some visitors express concern that the ratio of bulls to cows seems low; this condition is due primarily to hunters' preferences and Colorado Division of Wildlife license policies, and is therefore beyond the park's control. Visitors are increasingly aware of the threat

posed to elk and deer by chronic wasting disease; Cordova found that 54.5% of visitors surveyed agreed or strongly agreed that large elk populations can easily transmit diseases (Cordova 2000b). This survey was conducted in September and October when many visitors are coming primarily to view elk. The attitudes expressed by these visitors are not necessarily representative of visitors in other times of the year.

Lethal removal methods (specifically use of firearms) received the least support among visitors surveyed in 1999 (21.3%), even with donation of the meat to charitable organizations (Cordova 2000b). Fix et al. found that all forms of reduction, including fertility control, lethal removal, and wolf release, were acceptable for up to 50% of the national and Colorado respondents, and up to 60% of the Estes Park and Grand Lake resident respondents. Visitors strongly supported trapping and relocating elk as a management tool (acceptable or very acceptable to 58.9% of those surveyed (Cordova 2000b), but state regulations prohibit transporting deer or elk out of infected areas (CDOW 2003a), including the area that encompasses the park.

While hunting is prohibited in Rocky Mountain National Park, many visitors to the surrounding area participate in big game hunting. Elk are the favorite game among hunters in the area, with deer a close second. As shown in Table 3.9, in the Socioeconomic section, between 1999 and 2004, the number of elk hunters and deer hunters more than doubled in Game Management Unit 20, east of the park (CDOW 2005b). During the same period, total recreation days (a recreation day is a visit by one person to a recreation area for any part of one day) associated with big game hunters in Game Management Unit 20 roughly tripled, as shown in Table 3.11, below (CDOW 2005b). In Game Management Unit 18, west of the park, the numbers of elk hunters has declined slightly during the same period, while deer hunter numbers have varied between a low of 1,167 and a high of 2,535 (see Table 3.10, above). Table 3.12 shows the variation in recreation days associated with big game hunting in Game Management Unit 18 for each of those years (CDOW 2005b).

TABLE 3.11: GAME MANAGEMENT UNIT 20 TOTAL RECREATION DAYS

Year	Elk	Deer	Bear	Mountain Lions
2004	16,469	9,181	34	—
2003	12,439	8,648	3	35
2002	10,486	6,608	53	12
2001	8,896	4,110	17	80
2000	7,690	3,759	58	—
1999	6,742	3,846	—	—

Source: Colorado Division of Wildlife website <http://wildlife.state.co.us>

TABLE 3.12: GAME MANAGEMENT UNIT 18 TOTAL RECREATION DAYS

Year	Elk	Deer	Bear	Mountain Lions
2004	24,526	11,211	42	—
2003	25,263	8,098	25	22
2002	18,935	5,679	14	7
2001	19,555	5,105	4	6

Source: Colorado Division of Wildlife website <http://wildlife.state.co.us>

PARK OPERATIONS

Management of elk and vegetation and the visitors that enjoy these resources within the park requires the participation of five park divisions: administration, facility management, resource management and research, interpretation, and resource protection. All divisions are overseen by the park superintendent and assistant superintendent. The administration division does not expend resources directly to manage elk and vegetation within the park, but provides support for the other divisions that manage park resources and other activities in the park.

Park staff work throughout the park, managing visitors, resources, and activities, as well as facilities including two park museums and five visitor centers (Beaver Meadows, Fall River, Kawuneeche, Alpine, and Lily Lake).

Park Staff and Management Divisions

The park staff consists of 394 employees, divided among seasonal, part-time, and full-time staff across six divisions of management (Schuster 2005). The allocation of park budget among the divisions is shown in Table 3.13.

The divisions that are directly related to elk and vegetation management activities are Resources Management and Research, Interpretation, and Resource Protection. However, elk and vegetation management accounts for only a small part of the overall responsibility for all but two Rocky Mountain National Park employees, who spend much of their time on elk and vegetation management issues (Johnson 2005).

TABLE 3.13: DIVISION OF PARK BUDGET AMONG SECTORS: YEAR 2004

Sectors	Percentage	Dollars
Visitor Services	36%	\$7,429,280.00
Maintenance	31%	\$6,341,140.00
Resources Preservation	23%	\$4,673,580.00
Administration	10%	\$1,949,200.00

Source: RMNP NPS Webpage

Resources Management and Research

The Resources Management and Research Division includes 69 employees (Schuster 2005). Various staff from this division conduct wildlife management activities, site restoration, fire management, park planning, exotic plant control, and biological monitoring throughout the park and extending into Estes Park and Grand Lake. This group also coordinates the work of outside scientists who conduct formal studies within the park, such as chemists, hydrologists, biologists, social scientists, and archeologists.

The staff in this division are also responsible for coordination with other state and federal agencies managing resources in the region. The NPS staff interact with the Colorado Division of Wildlife in several capacities. In regard to elk, the Colorado Division of Wildlife conducts hunting/poacher management and destroys violent animals, among other tasks. The two agencies communicate closely during management activities or when an injured animal enters the boundary of the national park. NPS staff contact the Division of Wildlife when elk, deer, or carcasses suspected of chronic wasting disease are observed just outside the park boundary. The

Division of Wildlife occasionally assists the National Park Service with poaching incidents inside the park boundaries. The resource management staff currently coordinates with the Division of Wildlife to monitor elk populations that use both the park and the surrounding areas. Shared activities such as these are carefully managed in conjunction with the Colorado Division of Wildlife (Ronca 2005b).

The Resources Management Division conducts elk monitoring along several ground and aerial routes at different times throughout the year. Paid or volunteer park staff perform population counts and classifications (bull, cow, yearling, calf) on the established five park ground routes and population counts on the established seven town ground routes. Park staff monitor the ground routes in the park and in town for three consecutive days in conjunction with the first day of aerial monitoring (described below) in winter and in some years at other times throughout the year. The monitoring activities inside the park require approximately four hours per person per day and each route generally utilized two people. The staff time required for monitoring in the town is nine hours per person, in both the winter and summer. The park staff and contractors are also responsible for the compilation of monitoring results and developing reports which takes roughly 40 hours total.

Aerial monitoring for elk is conducted annually, during a suitable weather window from January to March. The five survey routes correspond to the ground routes and are in the elk east-side winter range, within park boundaries. This information is plotted and then modeled to determine the park population. The staff time required for aerial monitoring is about 28 hours total, which includes the pilot's, helicopter manager's, and two observers' time (Ronca 2005c).

Year-round monitoring [and mule deer live testing](#) for chronic wasting disease-infected animals within the park requires the specially trained staff to respond to reports of animals suspected of having chronic wasting disease. The chronic wasting disease team typically includes four full-time biological science technicians for seven months (September through December and March through May), but the structure of the team varies by season. They are responsible for [capturing and live-testing up to 200 mule deer annually, euthanizing deer that test positive for chronic wasting disease, responding to reports of deer and elk exhibiting clinical signs of chronic wasting disease, euthanizing chronic wasting disease clinical suspects, responding to reports of deer and elk carcasses that can be tested for the disease, and](#) subsequent transport of animals to a facility for chronic wasting disease testing and disposal of carcasses.

The Resources Management division is also responsible for maintaining the park's 26 research exclosures, which cover approximately 12 acres (Ronca 2004). Although no biological science technicians are currently monitoring these exclosures, they are still actively maintained.

Fire management in Rocky Mountain National Park is conducted through the Natural Resources and Research Division; however, the cooperation of several divisions is critical for the successful implementation of fire management activities. The staff are responsible for preparedness, fire suppression, hazard fuel reduction, prescribed fire implementation, and managing wildland fires for resource benefits (NPS 2004a). Fire management activities are planned according to the management prescriptions set forth in the fire management plan (NPS 2004a). Prescribed burning operations usually involve fuels control of ponderosa and lodgepole pines. The plan includes no actions for burning willow or aspen in primary winter and summer elk range. This plan follows the ban on burning aspen, willow, and upland shrub communities except where they occur in proximity to the wildland-urban interface. The three fire management units that include primary winter and summer elk range are the Fall River, Estes Valley, and Forest Canyon Fire Management Units. In Fall River and Estes Valley, fuels management actions are only approved for fire suppression or protection. This could include hand pile burning, manual fuels reduction,

or prescribed burning. In Forest Canyon, no fuels management actions are currently planned or approved.

Fifty National Park Service staff members participate in fire management efforts in Rocky Mountain National Park (NPS 2004a). The fire management staff in Rocky Mountain National Park is part of the Rocky Mountain Cluster of the National Park Service Intermountain Region, a shared cooperative of staff that also services Great Sand Dunes National Monument and Preserve and Florissant Fossil Beds National Monument.

Interpretation

The Interpretation Division maintains a staff of 37 employees. This includes 21 seasonal positions and 16 permanent positions including park operational staff, support staff, media staff, museum coordinator and park archeologist, and park volunteer coordinator. The interpretive staff provides information and education services at visitor centers and interpretive programs, as well as writing publications and creating exhibits. Visitor center hours and the number of programs that are offered by the park are directly related to the amount of staff available.

Interpretation programs are developed to convey the park's themes and core mission in a manner that is favorably received by the public; objective; and based on science, resources management, and park management goals. They include information that allows visitors to understand the relationships regarding the management of resources. Interpretive rangers are expected to keep current with issues related to their presentations, which constantly evolve.

The park's periodical educational materials contain information on the elk population and its effect on the vegetative habitat. The park newspaper, a significant information resource on the status of resource management issues in the park, is published four times per year. It is available at all visitor centers and is handed out at all park entrance gates. Additional materials available at the visitor centers are produced through a cooperating association. One of these documents specifically focuses on wildlife watching in the park, with a section devoted to elk. Other park publications containing elk information include the site bulletin, the *Elk Viewing Guide* (which highlights the park's fall elk viewing opportunities), and the *Guide*, a pre-visit informational handout produced by the cooperating association. The park Website is also frequently updated with information regarding the management of elk and their impact on the habitat. (Langdon 2005a).

Each interpretive program at the park integrates resource management information that reflects the themes defined in the park's comprehensive interpretive plan and various management issues. Permanent staff members meet each spring to decide the amount of interpretive programs that can be offered, based on budget, staff available, and scheduling for training (Langdon 2005a).

Some programs presented in the park address some aspects of the interaction of elk and vegetation in relation to other park resources. These programs include Moraine Park Nature Walk, Wildlife in Horseshoe Park, Alpine Aspects, and Importance of Being a Beaver.

Some evening campfire presentations in the summer also address elk management issues as part of the content. The only interpretive program that focuses completely on elk is "Elk Echoes," which is offered in the fall during the rut season.

Interpretive staff also develop and conduct educational programs for children, high school students, and adults that take place within the park. The interpretation done with K-16 educational groups and with youth and adult special interest groups use the elk/vegetation interaction as a context for the experiential study of ecosystem components (DeGregorio 2005).

Interpretation of elk management issues, including population and chronic wasting disease concerns, occur through informal contacts between the NPS staff and visitors at visitor centers or throughout the park grounds. The staff also educate the public beyond the boundaries of the park by outreach presentations to local service clubs, conservation organizations, and other interested groups.

Currently, no interpretive programs are dedicated solely to vegetative resources and loss of habitat, but these topics are included in the individual service plan objectives for the park that must be covered in the general interpretive programs for the public (Langdon 2005b). The existing programs that focus on ungulates in the park usually include a discussion of the condition of the habitat.

Another channel of information and education of elk management issues is the Lyceum program, which takes place at the Beaver Meadows Visitor Center. In this program, experts on various topics are invited to present information to the public related to park resource topics and the latest research, and to lead discussion of resource management issues. Elk management has been presented in the past and will continue to be a frequent topic in the Lyceum programming during the elk management plan/EIS process (Langdon 2005a). The Lyceum series has included the loss of vegetative habitat.

Park interpretive staff are also responsible for the training and oversight of the Elk Bugle Corps volunteer group. The 80-member group has been in existence since 1990. Volunteers in the Elk Bugle Corps are not NPS staff; however, they make an important contribution to the responsibilities of the interpretive staff and provide logistical support for the ranger staff during the elk rut season. Each night during the rutting season, two interpretive rangers assist in managing elk viewing visitors and present two nightly programs on the elk rut ("Elk Echos"), with assistance from 11 to 20 Elk Bugle Corps volunteers.

The primary tasks of the Elk Bugle Corps include:

- Patrolling areas of the park frequented by elk populations from August 29 to October 26.
- Provide information to park visitors about elk and the park.
- Provide visitor safety and traffic control.
- Help enforce restricted areas put into effect during the season.
- Report closure violations and other infractions.
- Observe and record visitor statistics information.

The Bugle Corps is a significant source of visitor contacts (28,000 to 30,000 per season), providing natural history facts and information regarding elk management issues. The volunteers receive training each year, including the most current status of management efforts to control the elk population. Collectively, the volunteers donate approximately 2,000 volunteer hours per fall season (Langdon 2004b). The Colorado River District of the park has recently begun a similar program of roving volunteers on elk patrol during the rut season to assist in educating visitors about elk and elk management in the park.

Resource Protection

The Resource Protection division supports 97 employees (Schuster 2005). This includes 20 seasonal and 15 permanent law enforcement rangers as well as 16 seasonal and one permanent backcountry rangers (Ronca 2005b). These employees protect the safety of park visitors and park resources. Most are law enforcement officers who perform search and rescue operations and

manage activities in the backcountry as well as front-country roads. Law enforcement rangers are commissioned officers who police the park (including poaching, traffic control, and automobile accidents) but also provide education on the park's resources and chronic wasting disease reporting. The division of duties among rangers is shown in Table 3.14, below.

TABLE 3.14: DIVISION OF DUTIES AMONG RANGER STAFF, YEAR 2004

Specific Duty	Summer		Winter	
	Seasonal	Permanent	Seasonal	Permanent
Law Enforcement	20	15	2 to 4 (intermittent)	15
Backcountry (non-law enforcement)	5	0	0	0
Rehab/Wilderness	2	1	0	1
Backcountry Office	10	1	0	1
Total	80	26	4 to 8 (intermittent)	26

Source: Lani Pettibone, personal communication, February 28, 2005.

The ranger staff that deal with elk management includes law enforcement rangers, backcountry rangers, and wilderness rangers. Law enforcement rangers are responsible for addressing elk-human conflicts. Typically, three to five incidents per year are reported, usually regarding a charging bull during the fall rut or a cow charging visitors to protect her newborn calf in June, the calving season (Langdon 2004b).

In the past, poaching patrol has been conducted by rangers in the Resource Protection division, occasionally in cooperation with the Colorado Division of Wildlife, along boundaries of areas with a significant amount of land that borders U.S. Forest Service land (Oliver 2005). In recent years, poaching incidents reported in the national park have increased.

Another major duty of the rangers is crowd and traffic control associated with visitors who come to view the elk each October and November. The law enforcement and interpretive rangers control traffic flow with help from the Elk Bugle Corps volunteers. When the elk are easily visible along the roadway in meadows and visitor levels along the roadway and traffic become unsafe, rangers sometimes herd the elk away by horseback for visitor and traffic safety.

The decrease in Rocky Mountain National Park seasonal staff occurs in autumn due to budgetary constraints, when elk-related activities in the park increase due to the rut season. The second week in October is typically the week with the highest visitation for the year. Poaching also increases at this time of year, due to the hunting seasons, but poaching patrols are reduced. The rangers most needed during the fall elk season are law enforcement and interpretative rangers.

Facility Management

The Facility Management Division employs 83 staff members in the winter and 135 in the summer. They are responsible for general upkeep of the park, including maintenance of park roads, park vehicles, and park facilities. Their primary tasks include snow removal, care of park buildings (plumbing, painting, carpentry, electrical), maintenance of utility systems (water laboratory), repair of backcountry bridges, care of stock animals and stables, and maintenance of trails. They also are periodically involved in reporting elk that may have chronic wasting disease.

The increased amount of visitation to the park in fall causes an increase in the demands on maintenance staff, due to greater use of facilities such as restrooms, trash receptacles, and campgrounds.

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